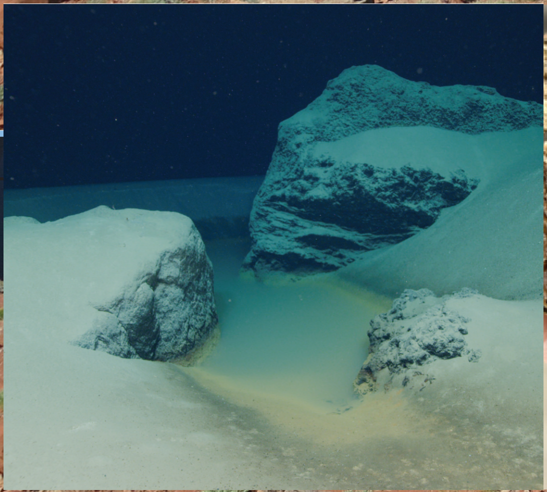
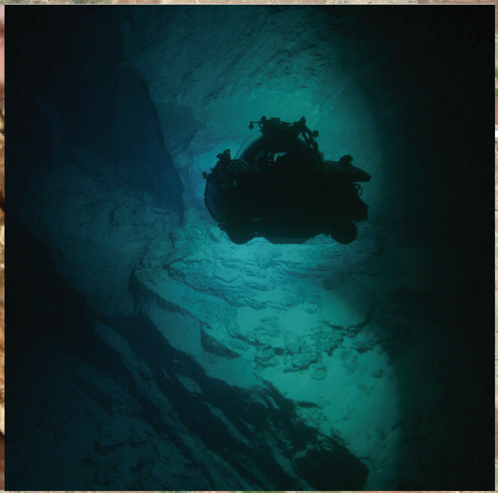
CENTER FOR CARBONATE RESEARCH

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

CSL - Center for Carbonate Research *and Education*

Prospectus 2024





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Carbon Capture Utilizations and Storage (CCUS)

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MISSION OF THE CSL – CENTER FOR CARBONATE RESEARCH

The mission of the CSL – Center for Carbonate Research is to conduct fundamental research in carbonates and transfer the knowledge to the industrial associates.

Our research program aims to comprehensively cover carbonates exploring new approaches, techniques and emerging topics. To reach this goal, our research projects integrate geology, geophysics, geobiology, and geochemistry and combine observational, laboratory, and theoretical approaches. Most research projects are interdisciplinary, but some are designed to advance knowledge in one specific area. This year the 16 projects are divided into five main topics:

- Rift basin and microbial carbonates
- Diagenesis and geochemistry of carbonates
- Shallow-water carbonates
- Carbonate contourite depositional systems
- Carbon capture utilizations and storage (CCUS)

The various projects are described in detail in this prospectus and are retrievable on the website www.cslmiami.info.

KNOWLEDGE TRANSFER

The CSL – Center for Carbonate Research transfers the research results to our partners through semi-annual meetings, our website, and publications.

We aim to inform our industrial associates about the knowledge gained from our studies and the newest research techniques that potentially can be incorporated into the workflow of projects or help to solve longstanding problems in exploration, production or carbon sequestration.

We present the research results of the projects described in the prospectus in a **Progress Report** in the form of an executive meeting in early summer and at the **Annual Review Meeting** in the fall. We provide each industrial associate with a digital version of our presentations and publications stemming from CSL sponsored research.

On our website, research results from previous years can be viewed in the archive section, providing a comprehensive database for many topics and geographic areas. Upon request, we also share original data sets with participatingcompanies.

In addition, we offer field seminars and in-house short courses.

A Certificate Program in "Applied Carbonate Geology" gives geoscientists the opportunity to become experts in carbonates.

2024 RESEARCH FOCUS

The research within the CSL is starting to move into a **new direction**. Several projects in shallow-water tropical carbonates of the Bahamian archipelago and the unconventionals in the Neuquén Basin are winding down. The focus shifts to other exciting areas and topics. In collaboration with OceanX, three research cruises to the rift basins in the Red Sea and the Gulf of Aqaba have collected a trove of data for the investigation of many processes in **active rift basin**. For example, the mixed depositional rift settings allow us to examine the climatic feedbacks that link terrigenous and marine processes. Likewise, the deep-sea microbialites from the Gulf of Aqaba expand our understanding of microbial processes.

With the help of ENI we are securing the cores from a **lowstand fringing reef** offshore Mozambique that grew during the last glacial maximum. These reefs drowned during deglaciation and were never subaerially exposed, giving us the opportunity to study **unaltered marine cementation** in a reefal systems. In addition, the diverse reef community is intimately covered with microbial crusts which again adds a new aspect to our microbialite theme. This core data will be a major focus in our **shallow-water carbonate theme**. In addition, two projects concentrate on **Joulter Cays**, Bahamas, the classic area of modern ooid formation. A third project assesses the reservoir properties of middle to late Eocene carbonates of the Apulia Carbonate Platform.

Even within our existing research themes we refocus our projects. In the **diagenesis and geochemistry** theme, the focus is on the rate and mechanisms of cementation in two environments that are not often studied. The first is the diagenesis on the slopes of the rift basin in the Gulf of Aqaba. This basin is unusually warm to great depth and could serve as an analog for diagenesis in the warm Cretaceous oceans. The second project aims to establish the early cementation rates of skeletal sands.

After successfully refining and calibrating the **clumped isotope method** for both the of Δ_{47} and Δ_{48} proxies, the methodology is now used to decipher multiple diagenetic overprints of meteoric and marine waters that is occurring in all shallow-marine succession affected by high-frequency sea-level fluctuations. In another project the dual clumped proxy is used ascertaining the degree of equilibrium in Modern carbonates, which is not possible with conventional stable isotope methods.

Our research effort in **carbonate contourite depositional systems** continues with maintaining and updating the carbonate contourite data base and with a project that investigates the geometry, unconformities, and thickness variation of the sediment drifts n along the Campeche Bank and Florida Straits.

In the **Carbon Capture Utilization and Storage (CCUS)** theme we continue the long-term experiments of the seal capacity of mudstone in petrophysical laboratory but with a re-design of the experimental set-up that allows for CO_2-Brine saturation prior to CO_2 injection. A second project is in 'blue carbon'; carbon sequestration by blue carbon ecosystems has been proposed to play a significant role in offsetting national CO_2. The goal of the proposed blue carbon project is to quantify the extent of blue carbon ecosystems in ~70 atolls that were mapped by the Global Reef Expedition. A third project addresses both, carbonate production by marine fish and their importance in the global carbon cycle. Carbonate grains produced by fish produce organic matter and carbonate minerals that are subsequently excreted to the water column. The production of this "**ichythyocarbonate**," has been greatly underestimated. A study aims to quantitatively define the role of ichthyocarbonate in the global carbon cycle.

2024 Planned Projects

Rift Basin and Microbial Carbonates

- Rift Carbonates, Brine Pools, and Deep Sea Microbialites in The Red Sea – Part III
- Climate Modulation of Siliciclastic Input into the Red Sea Rift
- Arsenic as a Chemical Biosignature in Microbialites: Does Accretion Mechanism Matter?

Shallow-Water Carbonates

- Mozambique Shelf Cores – Research Initiative
- Overfilling of Accommodation in a Modern Ooid Sand Body A Record of Climate (Storm Frequency) Change
- 50 years of Research on the Joulters Ooid Shoal: Impact on Carbonate Sedimentology and Diagenesis and Lessons Learned from an Invaluable Analog
- Reservoir Properties of the Apulia Carbonate Platform (Gargano Promontory, Italy)

Diagenesis and Geochemistry

- Early Marine Cementation in Holocene Skeletal Sands
- Slope Diagenesis in a Warm Ocean
- Temperature and Variations in the Salinity of Fluids Revealed by Clumped Isotopic Analyses
- Dual Clumped Isotopes (Δ_{47} and Δ_{48}) of Modern Carbonate Sediments
- The Carbon Isotopic Composition of Proximal and Distal Sediments in the Vaca Muerta Formation, Neuquén Basin Argentina

Carbonate Drift Deposits

- Decoding the Evolution of the Loop Current - Gulf Stream from Sediment Drifts

Carbon Capture Utilization and Storage

- Fish Diet Impacts the Role of Ichthyocarbonate in the Global Carbon Cycle
- Estimating Blue Carbon Storage Potential in Earth’s Remotest Atolls
- Testing Seal Capacity for Carbon Storage - an Experimental Approach – (Year 2)

2024 Reporting

We will report on our research findings twice during the year. In a virtual meeting in June we will give a **Mid-Year Progress Report** to inform the Industrial Associates of the status of the projects and the results in hand.

The detailed results of the individual projects will be presented at the **Annual Review Meeting in Miami** in October. Hopefully we will be able to meet in person. The dates for these two meetings are tentatively set at:

May 30, 2024 – Mid-Year Progress Report

Executive style presentation of the projects and results in hand followed by a discussion. The meeting will be online starting at 9 o'clock in the morning (USA-EST) and 3 pm (UTC+01:00) in continental Europe. The meeting is expected to last about 2 – 3 hours. We will send out a program and other details by early May.

October 21 - 22, 2024 - Annual Review Meeting

The results of the projects detailed in this prospectus will be presented at the **Annual Review Meeting in Miami, October 21 -22, 2024**. We will send out information on the logistics for the meeting in the second quarter of 2022.

The **fieldtrip** from in conjunction with the annual review meeting is to **Paradox Basin**, Utah will be **October 23 – 27, 2024.**

During the 5-day field trip we examine the upper Paleozoic rocks in the Paradox Basin of southeastern Utah that are the result of cyclic deposition of mixed carbonates, siliciclastics and evaporites. Deeply incised canyons along the San Juan River provide spectacular exposures of rocks. We will utilize these outcrops to examine the cyclic nature of Pennsylvanian strata and the vertical and lateral facies variations. We will observe the dimensions and heterogeneities of an exhumed algal mound field and relate it to subsurface data. The goals of the field trip are to illustrate fundamental processes in mixed sedimentation, high-resolution and mechanical stratigraphy.

RIFT CARBONATES, BRINE POOLS, AND DEEP SEA MICROBIALITES IN THE RED SEA – PART III

Morgan Chakraborty, Amanda Oehlert, Peter K. Swart, and Sam J. Purkis

PROJECT OBJECTIVES

- To characterize rift basin carbonates in an active maritime rift setting.
- To analyze a new dataset acquired in 2023 from the NEOM Brine Pool (Gulf of Aqaba) to evaluate the genomics and geochemistry of deep-sea extremophile microbial mat-forming communities.

PROJECT RATIONALE

The Red Sea and Gulf of Aqaba sedimentary basins are developed along the African and Arabian conjugate margins and are characterized by Late Tertiary rifts filled with siliciclastic, carbonate, and thick evaporite successions. In collaboration with OceanX, we have now conducted three research cruises to explore these basins, the first in 2020, the second in 2022, and now most recently, in 2023. All three cruises used the R/V OceanXplorer and had the common objective of exploring and further detailing the deep Red Sea rift offshore Saudi Arabia.

This project assembles a unique dataset spanning swath multibeam bathymetry, sub-bottom profiles, sample collections from submersible and ROV, and deep-sea coring. Work to date has focused on margin stability of the rift shoulders (Purkis et al., 2022a) and description of a complex of brine pools that we discovered at a depth of 1,770 m in the Gulf of Aqaba (Purkis et al., 2022b). Having had the opportunity to collect new cores in these pools, we are now using geochemical and genetic analyses to understand the sedimentary record preserved in these anoxic (and therefore not-bioturbated) settings and the geological relevance of the diverse and expansive extremophile microbial communities that they host.

APPROACH

The Red Sea is the youngest actively rifting marine basin in the world and it is also one of the few giant salt basins that is still evolving. Our overarching goal of this project is to use the Red Sea rift as a present-day analogue for rifted continental margins with adjacent "Atlantic-type" sedimentary basins. The Red Sea facilitates an examination of carbonate deposition in an active rift setting. In particular, the basin allows the interaction of shallow-water carbonates atop fault–bounded syn-rift highs to be studied. The analog is of broad interest because syn-rift carbonate platform strata can form important petroleum reservoirs within rift basin systems.

Our dataset allows the interaction between flowing sub-seabed Miocene evaporites and shallow-water carbonates to be examined in a nascent oceanic basin. At the present time, the Miocene evaporites of the Red Sea are covered by 200-300 m of hemipelagic Pliocene-Quaternary (PQ) overburden sediments, which appear to do a good job of preventing the halite within the evaporites from re-dissolving, except where exposed by faults or slumps. The PQ overburden would, however, have been much thinner or absent in the early Pliocene. Our dataset is interesting as it provides an analog for the likely seabed environment that occurred in the early Pliocene Red Sea and in early stages of other salt giants shortly after reflooding of their basins by seawater. Presumably, they were floored by patchy brine pools accompanied by exotic fauna, as seen at the NEOM brine pools. This kind of detail is hard to work out for the older margins such as off Brazil, though our observations hint at things to look for in those areas, such as evidence of undisturbed sediments within brine pools immediately or closely above the salt deposits. Why did those salt deposits not simply re-dissolve once those basins become reflooded with seawater after the desiccation phase? Seemingly the answer to that might partly in the stability of brine pools if diffusion is slow.

SIGNIFICANCE

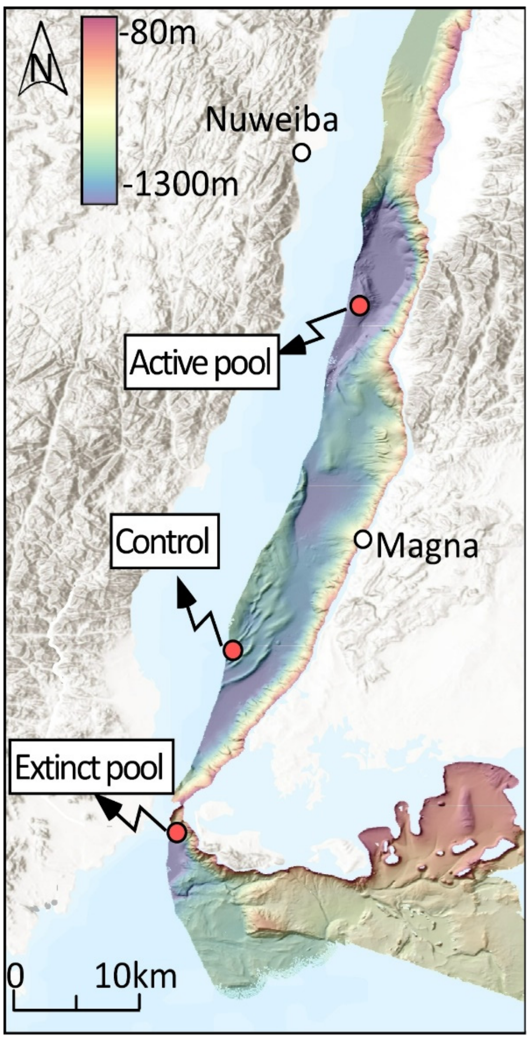

Figure 1: Multibeam data in the Gulf of Aqaba, Red Sea. Sample areas located in red.

The multibeam data assembled for this project allows for the direct imaging of the seabed structures generated by evaporite flowage, displacement, and withdrawal. Submersible and ROV dives have allowed direct sampling of the seabed structures associated with this movement. Discovery of the NEOM brine pools shows how sub-seabed evaporites can be dissolved by seawater penetrating along faults combined with hydrothermal circulation. Geologists commonly study microbialites but rarely in a deep-sea context as they are generally thought to be a shallow-marine phenomenon (Sprachta et al., 2001). The microbial fauna of the NEOM brine pool, however, implicates the potential formation of microbialites in bathyal-to-abyssal environments too. Further analyses will seek to determine if this microbial assemblage is actively trapping and binding sediments or precipitating new minerals. Preliminary genomic analyses reveal that the sediments surrounding the brine pool are just as diverse as the brine pool itself, while also harboring a distinctly different microbial assemblage (Fig 2). Thus, the biodiversity present in brine pool communities is even higher than previously thought, potentially opening the door for new research avenues in these extremophile environments.

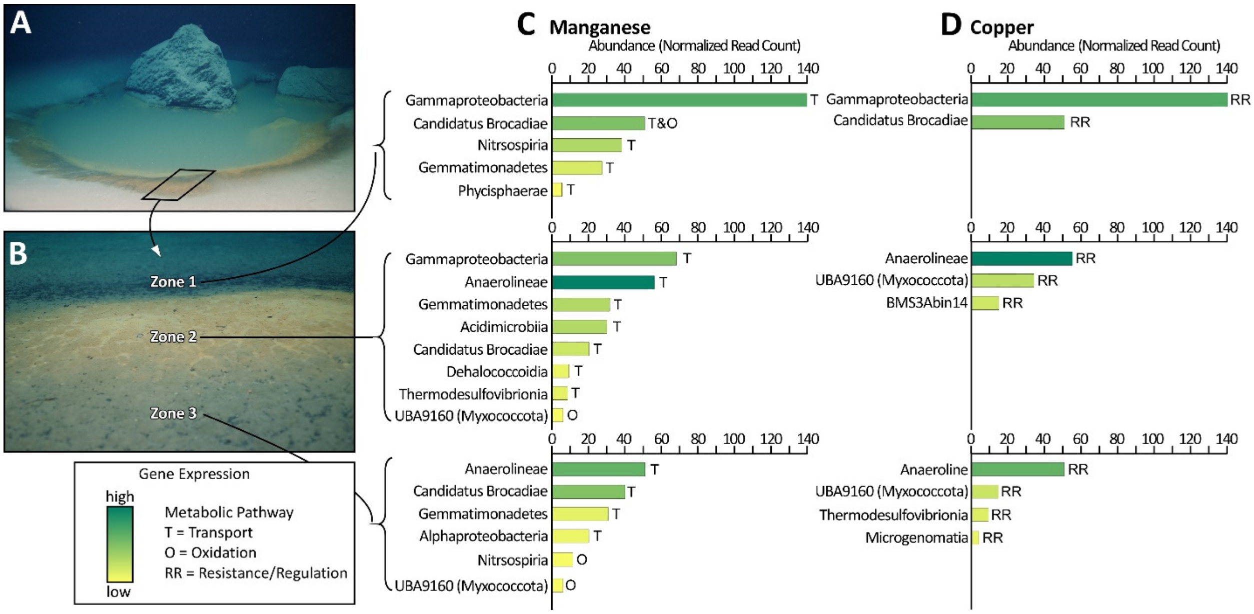

Figure 2: Expression versus abundance plots of microbes in the different microbial zones surrounding the NEOM Brine Pool, and their associated metabolic function. (B) The three microbial zones surrounding the brine pool. (C) Microbes present in the three zones utilizing Manganese. They are ordered based on abundance and shaded based on expression. Metabolic pathway stated on the end of the bar. (D) Microbes in the three zones utilizing Copper.

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Climate Modulation of Siliciclastic Input into the Red Sea Rift

Sam J. Purkis, Bolton J. Howes, Jake M. Longenecker, Morgan I Chakraborty, and Akos Kalman

Project Objectives

- To examine the climatic feedbacks that link terrigenous and marine processes in mixed depositional rift settings.

Project Rationale

Deep-sea sediment cores provide a comprehensive picture of past climate. Understanding the variability of past climate is essential to frame uncertainties surrounding future climate forecasts. Quaternary paleoclimate of the Middle East oscillated between periods of amplified rainfall and extreme drought (Arz et al., 2003; Parker et al., 2006; Purkis et al., 2010). The region is noteworthy for its high climate variability during the Holocene, an era which, at global scale, is considered to be relatively stable. Accordingly, scientists cast the Middle East as a climate change hotspot and a key calibration point for future climate projections.

The upland side of the northern Saudi Arabian Red Sea shoreline comprises ephemeral desert stream systems (wadis) that collectively drain >500,000 km^2 of mountainous drylands and deliver siliciclastic sediment to the coast in episodic flash floods. Periods of amplified rainfall in the region therefore induce pulsed delivery of massive volumes of siliciclastics into the rift basin. The near-absence of a continental shelf forces the photozoan-dominated carbonate factory to hug the resultant siliciclastic-dominated coast and delivers little studied mixed-system sedimentary interactions, specific to arid rift basins.

Approach

This study focuses on the Gulf of Aqaba, an extension of the northern Red Sea. In winter, the northern hemisphere Middle East Subtropical Jet (MESTJ) is situated above the Gulf (Sharifi et al., 2018). The MESTJ is a component of the jet stream and comprises a narrow and strong westerly wind belt. The position of the MESTJ and its strength mediate the intensity and location of precipitation over the Gulf of Aqaba and beyond (Ren et al., 2022; Wei et al., 2022). Under certain configurations, the MESTJ emplaces a large and humid warm air mass above the usually hyper-arid Gulf, generating extreme rains. These events can amount to several years of rain in a couple of hours (Klein, 2000).

Extreme rains fill the high mountain watersheds surrounding the Gulf, activate ephemeral rivers, so-called 'wadis', and transport freshwater plumes laden with terrigenous sediments into the sea (Fricke, 1996). By virtue of their high relative density, the plumes sink as muddy submarine hypo- and hyperpycnal flows (Mulder et al., 2001). These flows settle to the seabed as classic fining-upward Bouma-type turbidites, emplacing a sedimentary record of extreme rainfall events seaward of canyon heads. The fining-upward nature of individual turbidites conveniently distinguishes each rain event from that preceding it. Thus, counting and dating the terrigenous turbidite layers in seabed cores offers a means of reconstructing rainfall over geological timescales.

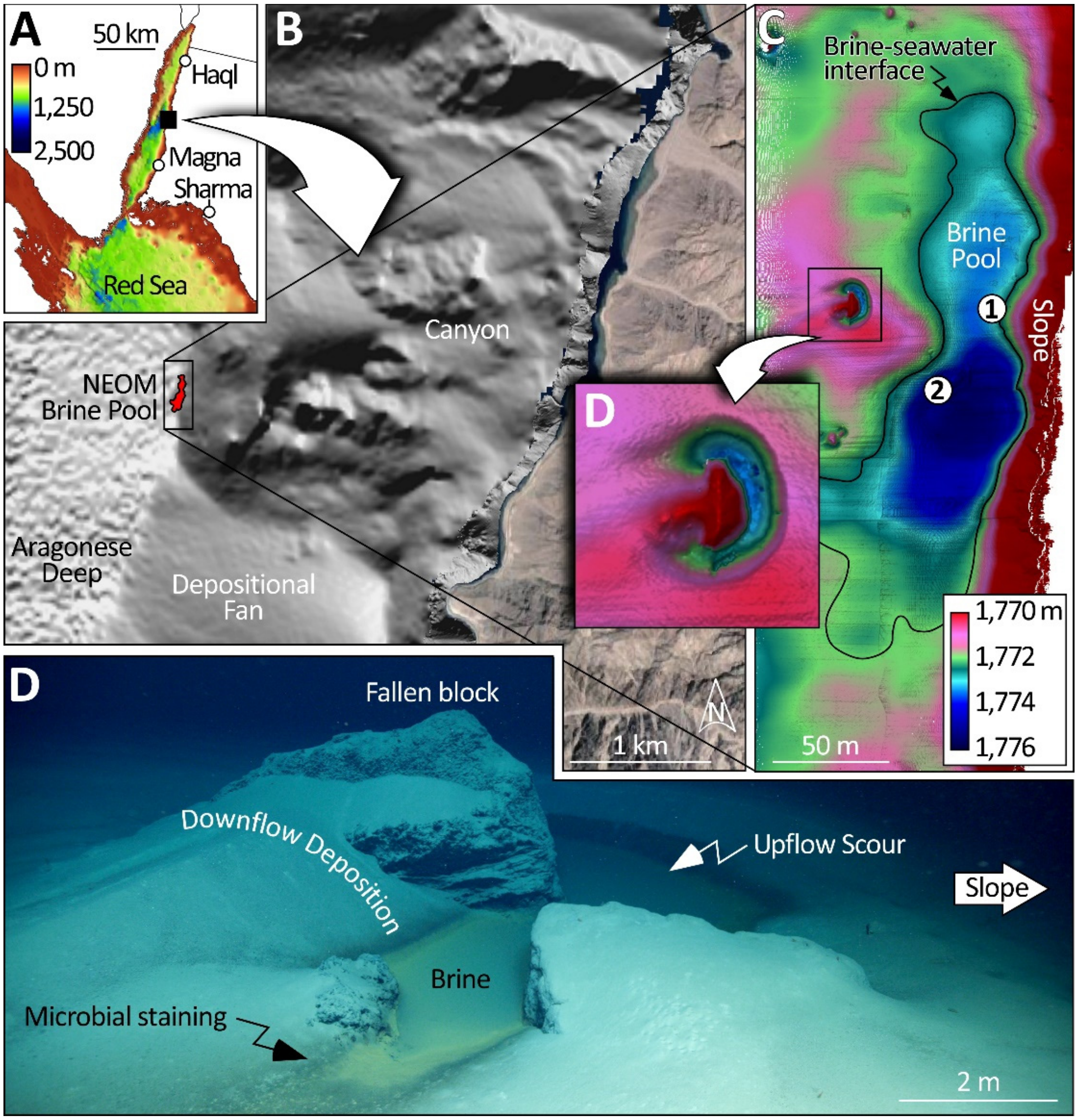

Figure 1. Depositional setting of the NEOM brine pool. (A) The brine pool is located at 1,772 m water depth at the toe-of-slope of the Saudi coastal margin in the Aragonese Deep, the deepest point in the Gulf of Aqaba. Mapped here atop hill-shaded multibeam data, the pool, situated just 2 km from the coast, is excellently positioned to receive episodic fluvial outwash from the Saudi coastal plain (B). High-resolution multibeam of the brine pool acquired from the Argus remotely operated vehicle (C) shows the brine pool to be 10,000 sq. m in area and 6 m deep at its deepest point. Two push cores (white circles) were acquired through the bed of the pool. Smaller brine pools have been created in seabed depressions created by blocks falling down the slope into the Aragonese Deep (D), which subsequently fill with brine. Note how the seabed scours landward of these blocks whereas sediment deposits seaward of them, indicating down-slope flow of cascading density currents.

SIGNIFICANCE

Arz et al. (2003) used flood deposits in deep-sea cores to reconstruct Gulf of Aqaba hydroclimate. Their study extends back 7,000 years and identifies amplified fluvial input between 9.25 and 7.25 kyr BP as representing the northern Red Sea humid interval. By 5.5 kyr BP, this input abruptly diminishes, marking the onset of regional hyperaridity. A crucial, confounding factor to linking flood deposits in cores to hydroclimate is the reworking of marine sediments by burrowing benthic organisms (bioturbation). Work by Steiner et al. (2016) emphasizes how bioturbation effectively erases short term events from the deep Gulf's sedimentary record. Their study, as well as those of Katz et al. (2015) and Bialik et al. (2022), advises that biological activity is capable of mixing many decades of sediment deposition. Bioturbation limited the temporal fidelity of the rainfall record retrieved by Arz et al. (2003) to broad precipitation trends played out over millennia.

The deep-sea 'NEOM' brine pool discovered by Purkis et al. (2022) at a water depth of 1,770 m in the Gulf of Aqaba offers a unique opportunity to reconstruct the region's hydroclimate because the pervasive anoxia, low pH, and hypersalinity of the brine excludes all metazoans. Thus, the sedimentary sequences that accumulate on the bed of the NEOM pool are entirely undisturbed by bioturbation. Moreover, all of the other pools so far discovered in the Red Sea trend along the central axis of the rift, far from land. Uniquely, the NEOM brine pool is located just 2 km from the coast (Fig. 1), perfectly positioned to receive fluvial outwash from extreme rains. Cores from the 10,000 m^2 pool retrieved by Purkis et al. (2022) extend back to 1.6 kyr and exquisitely preserve stacked mm-scale terrigenous Bouma sequences. In this study we pair the cores retrieved by Purkis et al. (2022) and others acquired in 2022, with computer simulations of the Gulf of Aqaba watershed outwash, to deliver the first high-resolution Late Holocene record of Red Sea hydroclimate.

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Arsenic as a Chemical Biosignature in Microbialites: Does Accretion Mechanism Matter?

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Project Objective

- Identify the mechanisms of arsenic incorporation in microbialites formed by a range of accretion modes within Hamelin Pool, Western Australia.

Project Rationale

Microbialites have dominated > 80% of the fossil record of Earth history, colonizing a variety of depositional environments. Throughout Earth history, the abundance of microbialites and the dominant mode of accretion have changed over time. Some modern microbial communities construct weekly lithified sheet mats where the production of organic matter exceeds mineralization. In relatively rare instances, modern microbial mats form fully lithified structures with topographic relief. Some modern structures are formed by mats that trap and bind sediments from their environment, while others accrete through microbial precipitation of micrite. In contrast, Precambrian discrete microbial buildups accreted mainly through direct precipitation of microbial micrite. Variations in microbialite deposits (discrete microbial buildups versus sheet mats) were recently hypothesized to reflect differences in the dynamic balance between environmental and microbial forces (Reid et al., 2024). This equilibrium determines the proportion of different microbial products, including organic matter, micrite, and trapped and bound grains. The Microbialite Balancing Act (MBA), a new conceptual model presented by Reid et al. (2024), aims to define the dynamic configurations of forces and products that ultimately determine the accretion mode of microbialites.

Driven by interactions between environmental and microbial forces, chemical elements are transferred between the MBA products. These products, especially the carbonate fraction, can act as geological archives for chemical elements and the biogeochemical reactions in which they participate. Arsenic is incorporated in accretionary products associated with various MBA configurations, producing microbialites ranging from sheet mats to discrete microbial buildups. For example,

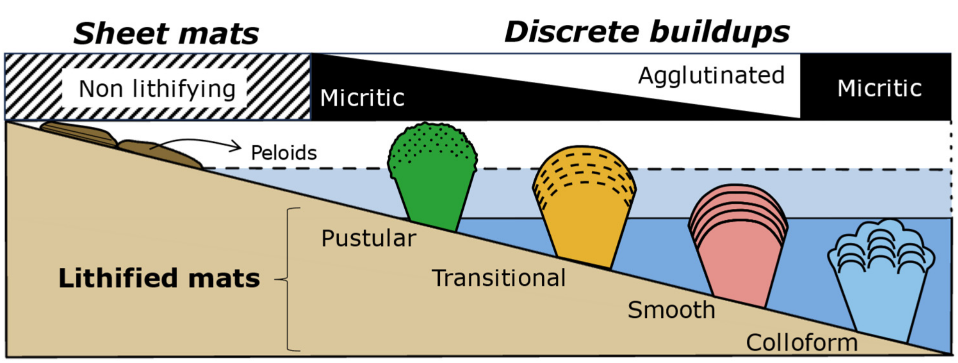

Figure 1: Growth model for microbialites in Hamelin Pool. After Vitek et al. (2022)

arsenic was noted as an element of biogeochemical interest in the 2.7 By micritic microbialites of Tumbiana (Sforna et al., 2014), the modern sheet mats in lake La Brava (Visscher et al., 2020), and the agglutinated microbialites of Hamelin Pool (Pollier et al., 2022). Therefore, arsenic may provide insight into the co-evolution of life and the environment in all microbialite accretion modes present in Earth's history. However, it is not clear how different configurations of the MBA, and thus different modes of microbialite accretion, influence the partitioning of arsenic within microbialite reservoirs, including organic matter and carbonate minerals.

APPROACH

Here we aim to quantitatively define the incorporation of arsenic into microbialites formed by variable accretion mechanisms in Hamelin Pool. Using a mass-balance approach, we will quantify [As] in seawater, sediments, and three distinct types of microbialites: 1) discrete microbial buildups (DMB) built by direct precipitation of microbial micrite; 2) DMB built by the trapping and binding of sediments; and 3) unlithified sheet mats that produce micritic grains. Sequential leaching experiments will isolate each microbialite reservoir for elemental analysis on an Agilent 8900 ICP-QQQ. To separate contributions from precipitated microbial micrite versus trapped and bound grains in concentrating arsenic in the bulk carbonate fraction, we will employ a mixing model.

SIGNIFICANCE

More than half of the world's conventional petroleum reserves are found in carbonate rocks, which include microbial carbonates. Variations in accretion mechanisms introduce heterogeneity in the petrographic characteristics of microbialite reservoirs, and the extent to which this heterogeneity impacts the geochemical record of the deposit remains unclear. The results of this study will address this knowledge gap by quantifying the impact of accretion mechanisms on the incorporation of arsenic into agglutinated, micritic, and non-lithifying microbialites from Hamelin Pool. Thus, our study will clarify interpretations of chemical biosignatures in microbial reservoirs deposited by accretion mechanisms that alternate through space and time.

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TEMPERATURE AND VARIATIONS IN THE SALINITY OF FLUIDS REVEALED BY CLUMPED ISOTOPIC ANALYSES

Peter K. Swart and Chaojin Lu

OBJECTIVES

- This work aims to establish and refine a new approach to unravel the temperature and $\delta^{18}O_{fluid}$ values of carbonates that have been overprinted numerous times by diagenetic events.
- In this method the Δ_{47} and $\delta^{18}O$ values are measured in the carbonates which allow the determination of the $\delta^{18}O$ of the diagenetic fluids ($\delta^{18}O_{fluid}$). Once the temperature and the $\delta^{18}O_{fluid}$ values are determined, the covariation of these parameters provides estimates of the fluid composition during changes in sea level.
- Preliminary data show that cores, previously interpreted as either being affected only by fresh or marine waters, have more complicated histories and supports evidence that regions of the cores previously thought to have been only affected by meteoric fluids, also have had significant cementation by calcite formed in the marine realm.

INTRODUCTION

The interpretation of changes in the $\delta^{13}C$ and $\delta^{18}O$ values of marine carbonates ($\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$) during early diagenesis is one of the most often used applications of stable C and O isotopes in carbonate rocks. Allan and Matthews (1982) outlined a series of changes in these values expected within carbonates exposed to freshwater diagenesis and these trends have been used by numerous workers to interpret their isotopic records. However, such samples are often a mixture of original unaltered materials and diagenetically altered/added carbonates, processes that occurred at different times and from fluids with varying salinities and $\delta^{18}O$ values. In order to unravel these patterns, we have developed a model using X-ray diffraction, clumped isotope, and conventional $\delta^{18}O$ and $\delta^{13}C$ values We have applied this to carbonate samples from the upper ~350 m of the Clino core, drilled in the Bahamas (Ginsburg, 2001) and present preliminary data.

THE MODEL

Assuming equilibrium and no solid-state reordering, clumped isotope values of carbonates provide the temperature of formation and/or diagenesis (Eiler et al., 2014). Using the $\delta^{18}O_{carb}$ value it is possible to determine the $\delta^{18}O_{fluid}$ value if the rocks are composed only of a single mineral. However if the mineralogy of the rock is known then the $\delta^{18}O_{carb}$ value can be corrected using estimates of the $\delta^{18}O_{carb}$ values of dolomite and aragonite based on previous studies (Swart and Melim, 2000; Swart et al., 2009). Once corrected the $\delta^{18}O_{fluid}$ values can be calculated using an equation linking the $\delta^{18}O_{carb}$ value and temperature (Kim and O'Neil, 1997). However, the $\delta^{18}O_{fluid}$ values and temperatures can still show a range of values, even

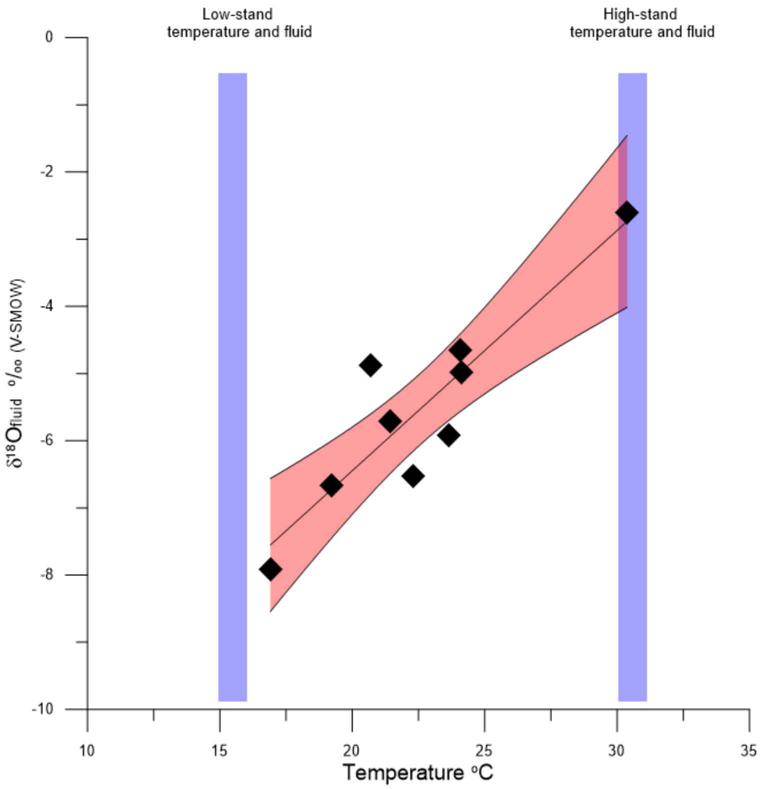

Fig. 1: Correlation between the $\delta^{18}O_{fluid}$ values and Δ_{47} derived temperatures for the upper 10 samples from Clino core (20 to 30 mbmp) showing a positive correlation and with end members representing diagenesis during periods of higher temperature with more positive $\delta^{18}O_{fluid}$ values and lower temperatures with more negative values.

over intervals of several meters that probably represent diagenesis at a range of temperatures and from different fluids.

Typically, if one examines a short interval (10 m) of the Clino core, the $\delta^{18}O_{fluid}$ values and Δ_{47} derived temperatures exhibit a positive correlation (Fig. 1). The simplest interpretation of this trend is that one end of the correlation, corresponding to the higher temperatures (25-30°C), represents alteration during sea level high stands. Conversely, the lower temperatures correspond to more negative $\delta^{18}O_{fluid}$ values, diagenesis by meteoric fluids during the low stands when temperatures were lower. The higher temperatures correspond to $\delta^{18}O_{fluid}$ values of -2 to -4‰ while the low temperatures to between values of -6 and -8 ‰. Using this approach it is possible to using a rolling window approach as applied during previous studies (Oehlert and Swart, 2019) to determine the slope and intercept of the correlation between temperature and $\delta^{18}O_{fluid}$. The goodness of the fit between temperature and the $\delta^{18}O_{fluid}$ values can be assessed by calculating the regression coefficient over an interval of 10 m. In a simple system that represents mixing between only two components, a low stand and a highstand, the regression coefficient would approach unity. In a system influenced by repeated sea level changes, the correlation coefficient would be lower as the system is overprinted by subsequent diagenetic events and there is mixing between multiple generations of calcite.

WORK COMPLETED

In order to test this approach, we sampled the Clino core at an interval of ~ 1 m between the start of recovery (~ 20 mbmp) to ~350 mbmp. At each interval we measured the mineralogy and Δ_{47} values of the carbonates (The $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ are measured as part of the determination of the Δ_{47} values). The $\delta^{18}O_{carb}$ values were corrected for amounts of aragonite and dolomite and the $\delta^{18}O_{fluid}$ values calculated from a moving window regression between the temperature and $\delta^{18}O_{fluid}$

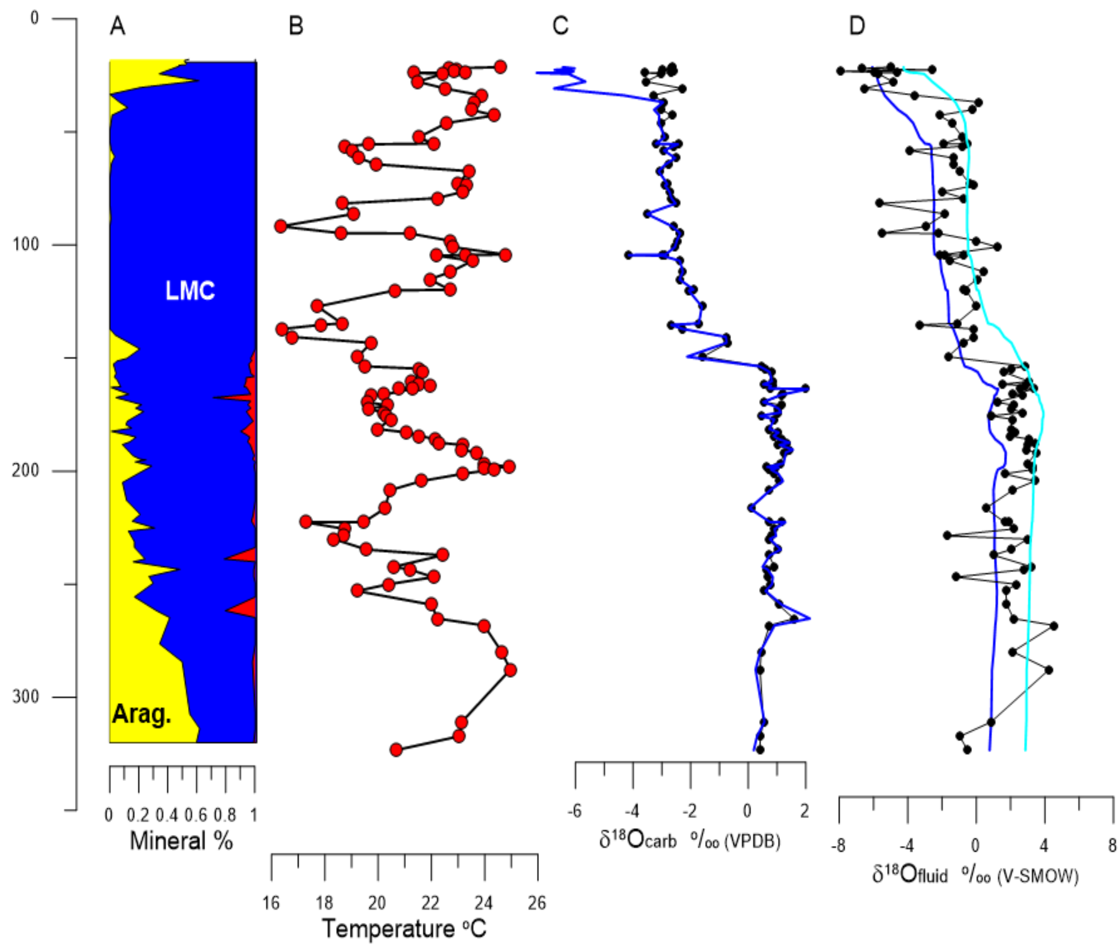

Fig.2: A) Mineralogy of interval in the Clino core between 20 and 350 mbmp, red= dolomite; B) Three point moving average of temperature calculated using Δ_{47} values; C) The $\delta^{18}O_{carb}$ values of bulk (black) and corrected for the presence of dolomite and aragonite (blue); D) Estimates of the $\delta^{18}O_{fluid}$ end members at 15°C (dark blue) and 25°C (light blue).

values. The mineralogy, calculated temperatures, corrected and uncorrected $\delta^{18}O_{carb}$ and $\delta^{18}O_{fluid}$ values are shown in Fig. 2. In Figure 2D the dark blue line represents calculated $\delta^{18}O_{fluid}$ values at 15°C and the light blue at 25°C. These data reveal that in the interval between 50 and 150 mbmp, previously only thought to have been affected by meteoric alteration, calcite components exist that were altered in fluid with $\delta^{18}O$ values more positive than 0 ‰ or in other words seawater. In the lower portion of the core (> 150 mbmp), the $\delta^{18}O_{fluid}$ values range between 0 and +3‰, perhaps indicative of saline surface brines and fluids originating affected by recrystallization deeper in the section.

PROPOSED WORK

1) Replicate all of the already measured Δ_{47} values in order to reduce the errors on the temperature estimates which presently are ~+/- 3°C.
2) Measure the Δ_{48} values which will help constrain disequilibrium.
3) Add additional geochemical markers (Na and S) that may help constrain the salinity of the diagenetic fluids.

Significance

There are several important findings from this study.

1) Based on the correlation between the temperatures and the δ^{18}Ofluid values, there appears to be low-Mg calcite forming from marine fluids within the zone previously thought to be solely affected by meteoric diagenesis. This LMC seems to be forming at temperatures between 25-30°C so probably during the high stands. During the low stands, meteoric calcite is forming at temperatures probably between 15-20°C.
2) Lower in the core (> 150 mbmp), LMC also seem to form over a range of temperatures (20-30°), with the fluid values falling between +1 and +3‰. Elevated values could reflect (i) evolved fluids arising from carbonate recrystallization at higher temperatures that migrated from deeper in the section, (ii) evaporated surface waters, or (iii) reflect disequilibrium arising from microbial sulfate reduction.
3) The δ^{18}Ofluid values in the upper portion of the core are more negative than current δ^{18}O values for rainfall in the Bahamas, indicating perhaps a wetter climate during the last interglacial, a finding supported by previous research.

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EARLY MARINE CEMENTATION IN HOLOCENE SKELETAL SANDS

Mara R. Diaz, Gregor P. Eberli and Ralf J. Weger

PROJECT OBJECTIVES

- To elucidate the effect of microbial communities in diagenetic processes that lead to the cementation of skeletal grains. Toward this end, *in vitro* incubation experiments will be conducted with skeletal grains in the presence and absence of microbial marine communities.
- To characterize the microbial communities that are potentially involve in skeletal cementation processes.
- To determine whether microbial exudates of exopolysaccharide substances (EPS) influence agglutination and early cementation of skeletal grains.
- To document the development of inter/intragranular cements and identify textural forms and mineral microstructure composition of early marine cementation areas using petrographic thin-sections and SEM/EDS.

PROJECT RATIONALE

Although there are number of studies suggesting that early marine cementation is accomplished inorganically, this notion has been questioned as many micritic early marine cements denote microbial fabrics consistent with microbial mediation. Early micrite cements are often obscured by multiple generation of cements of variable crystal shapes (Dravis, 1979; Hillgärtner et al.,2001; Diaz and Eberli 2022). Based on recent studies with a cohort of field collected samples from the Bahamas and Hamelin pool, we hypothesize that initial cementation and stabilization of carbonate sediments result from the interplay of metabolic activities and passive processes influenced by extracellular polymeric substances (EPS) and entombment of cells. Results from *in vitro* experiments undertaken with ooids in the presence and absence of native microbial communities support this hypothesis (Diaz and Eberli, 2022). We have shown, for instance, that early cements and grapestone formation is a fast process (30 to 60 days), primarily assisted by exudates of microbial EPS, microbial filaments and metabolic activities within the sedimentary grains.

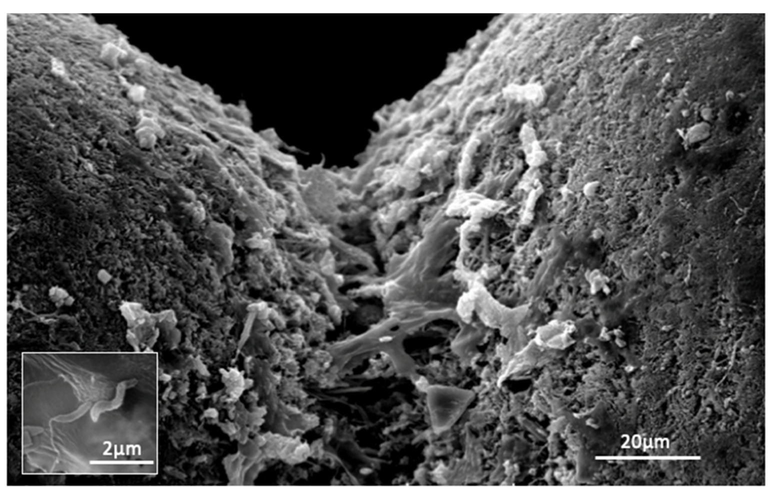


Figure 1. Example of agglutination of ooid grains assisted by EPS and biofilm bacteria after 30 days incubation (from Diaz and Eberli, 2023).

In this new experiment, we plan to establish whether early cementation in skeletal grains follow a similar trend and rate of cementation. Given that ooids harbor an astonishing rich diversity of micro-organisms we expect cementation of skeletal grains to occur at a lower pace.

SAMPLE SITE

We will collect samples from the White Sands in the Florida Reef Tract and repeat the experiment following the protocol of the ooid study (Diaz et al., 2023).

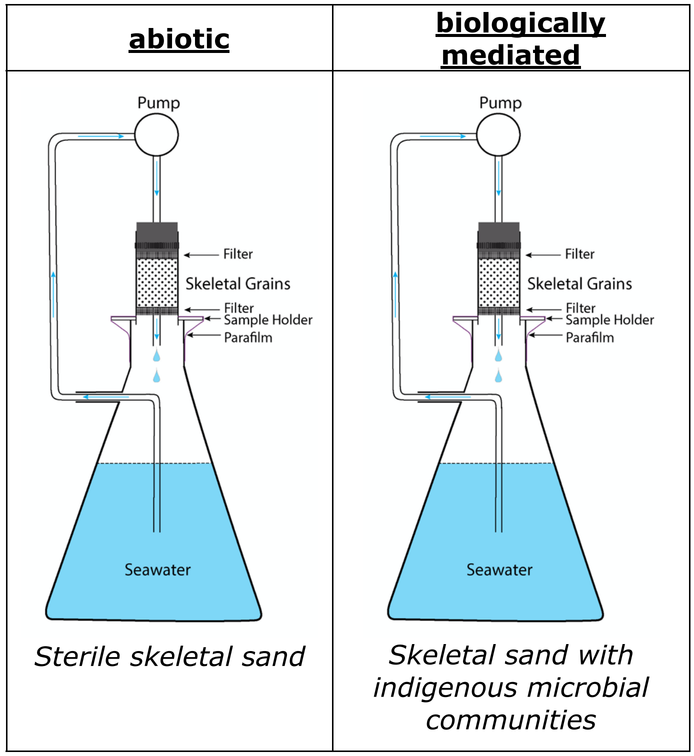
Figure 2: The Florida Reef Tract is a patchwork of coral reefs and high-energy skeletal sands (White Sands). Well-sorted skeletal sands will be collected using a protocol that preserves the indigenous microbial communities (Diaz et al., 2023)

APPROACH AND METHODOLOGY

The experimental approach: We will use two sets of incubations - representing abiotic and biologically mediated precipitation (see inset). In vitro experiments will be undertaken in chambers containing skeletal grains that have undergone sterilization (to ensure axenic or microbial free conditions), whereas microbially mediated precipitation will use freshly collected skeletal grains with their native flora. The packed grains are sealed with two porous disks, permitting the inflow/outflow of seawater through the sleeve. A continuous inflow of sterilized seawater (seawater not enriched with nutrients) will be applied. The samples will be subject to alternating cycles of daylight and dark conditions to allow 12 hours photosynthetic processes and 12 hours darkness to stimulate heterotrophic activity under low oxygen conditions.

Visual inspection of contact areas to identify grain binding and microbial colonization will be conducted at different time intervals (0 to 4 months) using petrographic thin sections and SEM analysis. SEM-EDS analysis will also be used to document and characterize the mineralogy of early cements as well as the potential involvement of extracellular polymeric substances (EPS) and presence of ACC as a precursor to cementation processes.

Characterization of microbes associated with the evolution of cements will be carried out using SEM analysis. Characterization of the skeletal grains and cements will be done on epoxy-impregnated thin sections.



SIGNIFICANCE

This study will provide insights on the role of microbes and associated EPS in cementation processes in carbonate skeletal sands. In addition, the results will reveal how much the rate of cementation in skeletal sands differ from those in ooid sands that contain a high-diversity microbial community. There are indications from other studies and in the geologic record that the rate of cementation might be lower in skeletal sands. Grammer et al. (1999) conducted a cementation experiment with ooid samples that were suspended above the sea floor at various depth across the margin of Great Bahama Bank. Partial lithification by fibrous aragonite cement was observed within 8 months in water depths of up to 60 m and complete lithification in 20 months (Grammer et al. 1999). The experiment also included skeletal sand but the cementation was minimal over the same time intervals and was not reported (Grammer pers. comm.), indicating a reduced rate of cementation compared to the ooid samples.

In the geological record, neritic skeletal sands especially in cool-subtropical and cool-water settings can be loosely cemented even when they are many million years old. It has been speculated that early removal of aragonite prevents the early cementation so that lithification is delayed until substantial burial and chemical compaction (James et al., 2005). Another characteristic of (temperate) skeletal sands is the near absence of micritic envelopes that are formed by endolithic borers (Betzler et al., 1997). The absence of micritic envelopes might also indicate a smaller role of microbial organisms in the cementation process compared to the one in ooid sands. Together, decreased microbial activity and delayed cementation produce highly porous and permeable rocks with excellent reservoir quality (Ehrenberg et al. 2006).

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DUAL CLUMPED ISOTOPES (Δ_{47} AND Δ_{48}) OF MODERN CARBONATE SEDIMENTS

Chaojin Lu and Peter K. Swart

PROJECT OBJECTIVES

- Measure the Δ_{47} and Δ_{48} values in modern biogenic and abiogenic sediments.
- Using the dual clumped proxy to ascertain the degree of equilibrium in Modern carbonates.
- Understanding the mechanisms of sediment formation (e.g. direct precipitation or breakdown from existing allochems).

PROJECT RATIONALE

The application of clumped isotopes has caused a revolution in the Earth Sciences. By examining the difference between the measured and the theoretical 47/44 mass ratios, the calculated value (Δ_{47}) has been found to be directly related to the temperature of carbonate formation/alteration (Wang et al., 2004; Ghosh et al., 2006). However, some carbonates, such as corals (Thiagarajan et al., 2011; Saenger et al., 2012), cave calcites (Daeron et al., 2011; Affek et al., 2014) and microbial associated dolomites (Murray et al., 2021), show unrealistic Δ_{47} temperatures attributable to non-equilibrium processes during their formation. Recently, it has been possible to also measure the Δ_{48} value and when used together with the Δ_{47} value, these two clumped species are known as the dual clumped isotope proxy. This coupled proxy is able to discern the kinetic isotope effects (e.g. CO_2 absorption and degassing) present in corals (Bajnai et al., 2020), cave calcites (Fiebig et al., 2021), spring carbonates (Parvez et al., 2023), and microbial-induced dolomites (Lu and Swart, 2023) (Fig. 1). In this study we use the dual clumped proxy to better understand the formation of sediments on the Great Bahama Bank (GBB), the origin of which has long been controversial (Broecker and Takahashi, 1966; Shinn et al., 1989; Morse et al., 2003; Swart et al., 2014; Purkis et al., 2019; Purkis et al., 2023). The samples used in this study were collected by Swart et al (2008) and Reijmer et al. (2009) and represent a range of compositions from mudstone to grainstone.

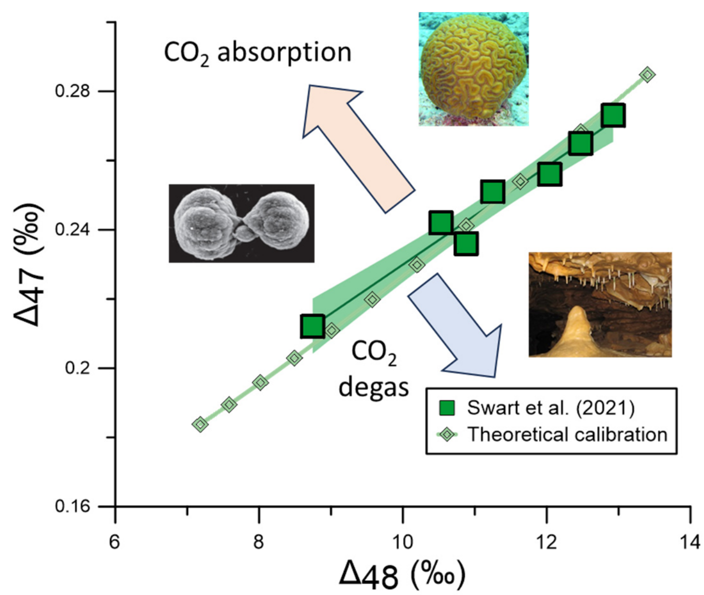

Figure 1: The crossplot of Δ_{47} and Δ_{48} values and differential kinetic behaviors in different carbonates.

Preliminary Data

The preliminary clumped isotope data shows that while there are no statistically significant differences in the Δ_{47} values between the different facies, the Δ_{48} values are significantly elevated in the mud dominated facies. (Fig. 2A and B). When comparing the Δ_{47} and Δ_{48} values to the calibration line of Swart et al. (2021), most of the muddy sediments (mudstone and wackestone) fall below the calibration line (Fig. 3C). In contrast, the grainy sediments (packstone and grainstone) appear to have a bimodal distribution, with values falling not only below the calibration, but also above (Fig. 3C). The possible reason for those variations of Δ_{47} and Δ_{48} values can be explained by multiple sources of sediments and the different disequilibrium formation processes by which these components were formed.

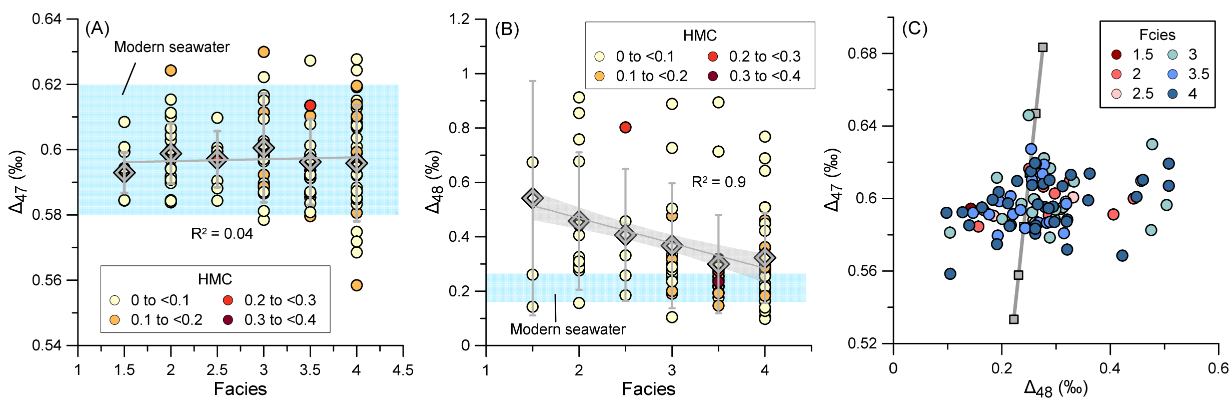

Figure 2: The crossplot of Δ_{47} and Δ_{48} values depending on facies in the GBB; a facies number of 1 corresponds to a mudstone, while a facies number of 5 is a grainstone; (A) The Δ_{47} values in different facies; (B) The Δ_{48} values in different facies; (C) The Δ_{47} and Δ_{48} values in different facies compare with the calibration line. From Facies 1.5 to 4, Modern sediments become grainier.

The spatial distribution of the Δ_{47} and Δ_{48} values show the heterogeneous Δ_{47} temperatures across the platform top. The Δ_{47} temperatures of the muds show lower Δ_{47} temperatures (<25°C) than those (>25°C) in the western margin (Fig. 3A). In addition, the area in which the whitings are found show a significant higher Δ_{48} values than the marginal area (Fig. 3B). This indicates that the intense precipitation associated with disequilibrium processes occurs in the intraplatform in which the mud accumulates.

Proposal Work

In order to further investigate the kinetic effects of dual clumped isotopes in modern sediments on GBB, we propose to; 1) Continue to measure Δ47 and Δ48 values of surface sediments of all the ~ 260 samples collected in triplicates; 2) Some preliminary measurements have been made on Δ47 and Δ48 values of red and green algae and these values appear to plot on the calibration line proposed by Swart et al. (2021). However, more species, replicates, and locations need to be measured and compared with the modern sediments; 3) Evaluate the influence of contamination of the Δ_{47} and Δ_{48} values. The Δ48 value had been previously used as a measure of contamination of the Δ_{47} value of a sample. It is important to make sure that, the Δ_{48} values that are measured, particularly values that are more positive than expected, are not artifacts.

SIGNIFICANCE

This study will establish base line values for the Δ_{47} and Δ_{48} values of Modern sediments as well as casting light on the origin of some of the more controversial sediments, such as the muds in the GBB. Preliminary data suggest that all the surface samples on GBB have formed in disequilibrium with respect to the Δ_{47} and Δ_{48} values, a finding that has profound implications on the use of these proxies in the geological record.

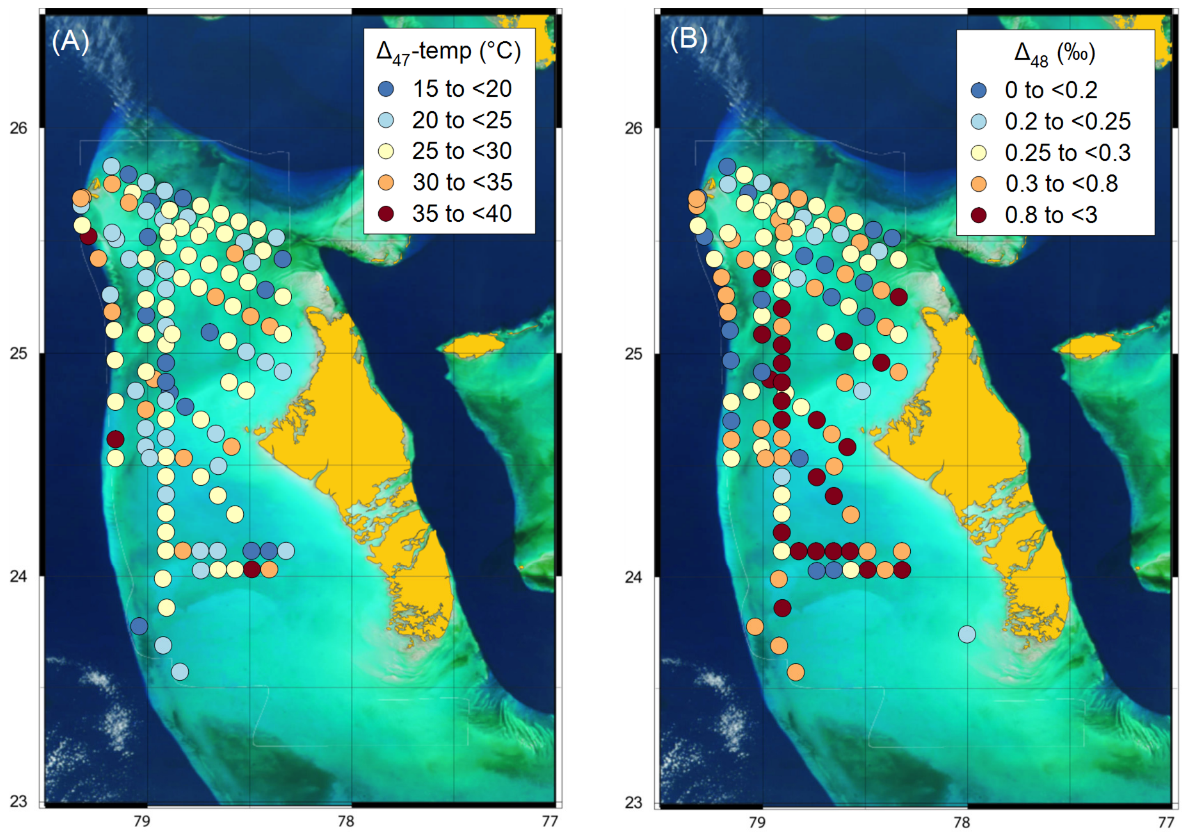

Figure 3: The distribution of Δ_{47} temperatures and Δ_{48} values in the GBB.

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SLOPE DIAGENESIS IN A WARM OCEAN

Ellie Barkyoumb, Ralf J. Weger, Sam J. Purkis, Mara R. Diaz, and Gregor P. Eberli

PROJECT OBJECTIVE

- Analyze slope carbonates from the Gulf of Aqaba, with the goal of revealing what organic and inorganic mechanisms are at play to stabilize and bind sediments in this location.
- Determine the role of microbial cements on the stability of the slope.

PROJECT RATIONALE

The Gulf of Aqaba is located along the African and Arabian margins and is unique because it is a part of the youngest actively rifting marine basin on Earth. Previous research conducted in this area has revealed the presence of several biologically complex brine pool ecosystems, as well as large evaporite deposits that are Miocene in age (Purkis et al., 2002). Another unique feature of the Gulf of Aqaba is that unlike most modern ocean basins, temperatures do not significantly decrease with depth. The temperatures in the Gulf of Aqaba are above 21°Celsius, even at depths of 1700 meters. Interestingly, the oceans of the Cretaceous did not experience thermohaline circulation, leading them to be relatively warm at extremely deep portions of the ocean. As such, there is potential for the slopes of the Gulf of Aqaba to be a proxy for what slopes were constructed of in the Cretaceous.

SAMPLE SET

We plan to analyze a total of 30 samples that were collected by the ROV Neptune, deployed on research cruises in 2020 and 2022, in the Gulf of Aqaba and surrounding areas. The samples were collected from different depths from 0 to 700 meters. The samples vary extensively with depth; at shallower depth they are encrusted by a diversity of brightly colored fauna, while deeper samples have a darkened exterior due to manganese and iron staining. In addition, there are textural differences. Samples from deeper areas along the transects are better sorted and finer grained than those along shallower portions of the transect. Porosity and texture vary significantly within samples collected at

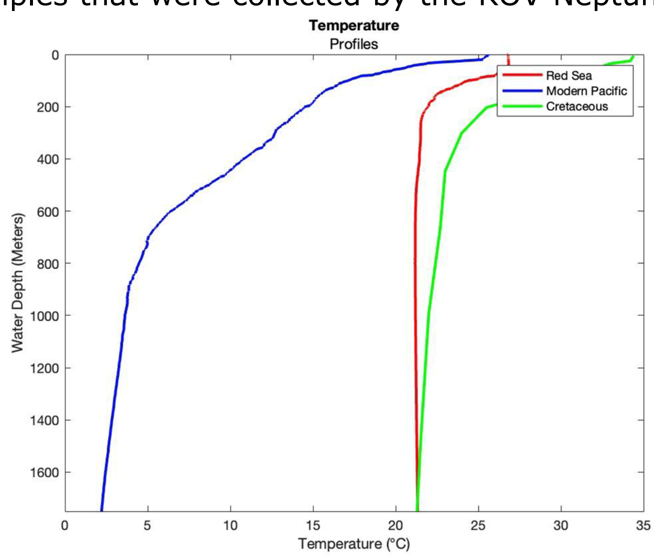

Figure 1: Temperature profile of the Red Sea, Modern Pacific and the Cretaceous. The Red Sea profile is unusual as it remains of warm temperature to great depth. As such it is similar to what is believed the Cretaceous ocean profile.

different depths, with some samples showing more evidence of biological activity and cementation.

APPROACH AND METHODOLOGY

Figure 2: Hand sample of the slope from the Gulf of Aqaba with abundant microbially induced cementation.

The slope samples of the Gulf of Aqaba will be studied regarding their composition and how sediments are bound and cemented. Visual inspection and description of the samples will be followed by the analysis of thin sections under a petrographic microscope to determine the grain composition and diagenetic alterations. Several samples display abundant microbially induced cementation. Characterization of microbes associated to the evolution of cements will be carried out using SEM analysis (Diaz and Eberli, 2022).

SIGNIFICANCE

The temperature profile of the Gulf of Aqaba, and the red sea in general, potentially provides an analog of the oceans of the Cretaceous period, when global climate was significantly warmer than it is in modern times. Consequently, the results of this study likely provide new insights into the formation and diagenesis in deep and warm waters that might potentially be different from diagenetic processes in the modern oceans.

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The Carbon Isotopic Composition of Proximal and Distal Sediments in the Vaca Muerta Formation, Neuquén Basin Argentina

Juliette Brophy, Ralf J. Weger, Gregor P. Eberli, and Peter K. Swart

Project Objectives

- Evaluate the ability to use $\delta^{13}C$ values from organic material to correlate between different sections within the basin, sections kilometers apart, in both proximal and distal positions.
- Re-validate that the $\delta^{13}C$ values of organic material ($\delta^{13}C_{org}$) are unrelated to changes in the total organic content.
- Confirm that $\delta^{13}C$ values of organic material can be used to correlate coeval sections within a basin more accurately than the $\delta^{13}C$ values of carbonate.

Project Rationale

The $\delta^{13}C$ values of carbonate and organic material within sedimentary deposits have been studied extensively and variations have been interpreted principally as changes in the rates of organic carbon production relative to burial and preservation (Hayes et al., 1999). Previously we studied the $\delta^{13}C$ values of organics and carbonates from 800 m of continuous, Late Jurassic to Early Cretaceous strata (~ 15 Myrs) exposed in the Neuquén Basin, Argentina (Rodriguez Blanco et al., 2019; Rodriguez Blanco et al., 2020; Tenaglia et al., 2020). The data provided a unique opportunity to compare this high-resolution $\delta^{13}C_{org}$ record to other published organic carbon isotope records from the same time period sourced in Atlantic, Arctic, and Tethyan sections. The data from the Vaca Muerta showed correlation to several globally distributed locations that show a large negative isotopic excursion of organic carbon ($\delta^{13}C_{org}$) of over 4‰ (V-PDB) and to a minimum of −30.3‰; an anomaly that has been named the 'Volgian Isotopic Carbon Excursion' (VOICE).

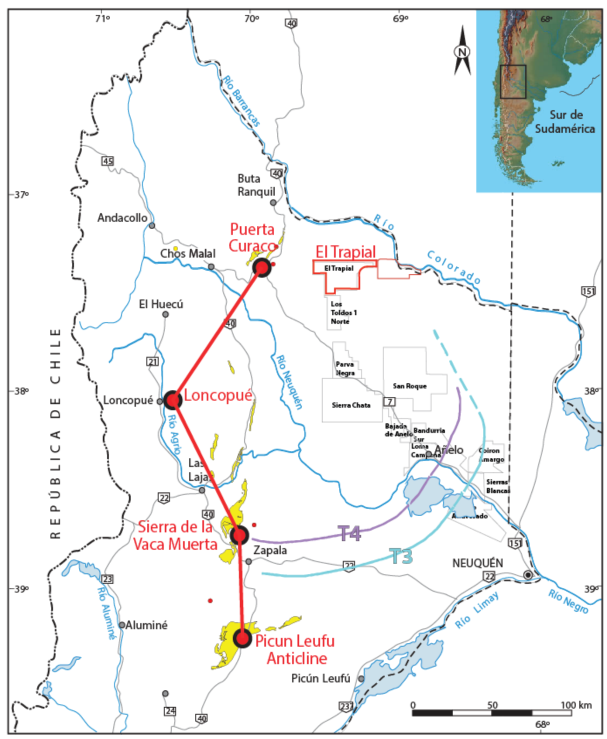

Figure 1: Location of outcrops in the Neuquén Basin. Box around Chos Malal Curraco indicates location of outcrop location. Stars indicate locations of published data used in this study for comparison.

WORK PROPOSED

We have obtained samples from approx. 350m of measured section of outcrops at the Picun Léufú anticline, the Tithonian portion of the Vaca Muerta Formation in a proximal setting. We have already carried out several studies of the variation of $\delta^{13}C$ and $\delta^{13}C_{org}$ values on the cores and measured sections in the basinal portions of the Vaca Muerta Formation (Rodriguez Blanco et al., 2022; Weger et al., 2023) and plan to perform the same analysis on these newly obtained proximal, time correlative samples.

SIGNIFICANCE

This study represents a combined study of the $\delta^{13}C$ values of organic and inorganic material found within the Neuquén Basin in Argentina. The $\delta^{13}C_{org}$ values appear to be unrelated to the global patterns in $\delta^{13}C_{carb}$ values, but they show similarity to patterns seen in $\delta^{13}C_{org}$ values at several boreal localities. This study will provide a detailed comparison of $\delta^{13}C$ values of carbonate and organic carbon and their variations between coeval distal and proximal locations. Key questions to be answered is if changes in $\delta^{13}C$ values proximal and/or distal behave correlative within the Neuquén Basin.

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Mozambique Shelf Cores – Research Initiative

Gregor P. Eberli, Ricardo Argiolis[1], Iva Tomchovska, Ralf J. Weger, James Klaus, Peter K. Swart, Amanda Oehlert, and others.
2) EniProgetti SpA

Goals of Project

- To decipher the initiation, growth and drowning of the fringing reef during the last glacial maximum.
- To assess the composition of the reef and the contribution of microbial crusts in stabilizing the reef.
- To thoroughly analyze the diagenetic alteration in this reef that was never exposed to fresh water.
- To produce a comprehensive petrophysical data set of the core material that includes porosity, acoustic velocity, and resistivity.

Introduction And Rationale

The slopes above the newly discovered giant gas fields offshore Mozambique (Fonnesu et al., 2020) revealed a long, approximately 40 m thick fringing reef that crested at -95 m water depth. The reef started to grow during the Last Glacial Maximum (LGM) at approximately 20 kyrs and drowned during the subsequent deglaciation. Such lowstand reefs have been cored in a few places around the world, including offshore the modern Barrier Reef and Tahiti (Camoin et al., 2006; Heindel et al., 2012). However, these earlier borings have not achieved the level of core recovery as those of Mozambique. The shareholders have released these cores to the CSL – Center for Carbonate Research- for scientific study.

We are expecting the official release from the government of Mozambique. A 2 m section was made available to us a couple of years ago. It showed a diverse coral community with several species but also thick crusts of greyish microbialites and microbial pellets inside the coral framework (Tomchovska et al., 2022).

Two samples collected for C-14 dating from this section yielded ages of 13400 and

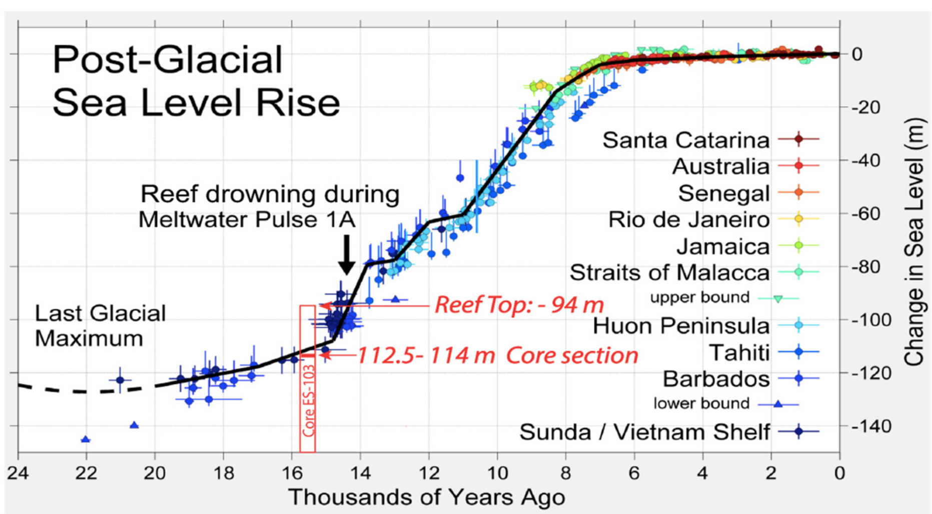

Figure 1: Core position within the post glacial sea-level rise. This lowstand reef that crested at -94 m has a diverse coral community and encrustations of microbialite (M) as well as calcareous red algae (CR).

13600 kyrs, documenting reef growth shortly after the LGM during the deglaciation and the accelerated sea-level rise event called Meltwater Pulse 1A (Figure 1).

The Mozambique cores (Figure 2) will provide a unique opportunity to study lowstand reef complexes that have never been exposed to freshwater diagenesis. Given the high level of preservation, these cores are of intrinsic value as they represent an unaltered geological record.

Analyses of these cores will address several fundamental topics.

These include 1) the evaluation of seawater composition and temperature during the LGM, 2) the timing and rate of sea-level rise during the early deglaciation, 3) early marine diagenetic processes, 4) the identification of the coral species and their changes from the LGM through the early stages of the deglaciation, 5) the role of microbial crusts that have been documented as important components of reef environments during the LGM, and 6) relate the pore structures to the petrophysical properties of these carbonate rocks cemented solely in the marine realm.

Planned Tasks

4) Curation of core: The cores will be cut longitudinally into two halves. One half will be the archive core, which will be photographed and preserved, while the other will be used as a "working" half for a myriad of analyses, including petrographic, geochemical and petrophysical analyses.
5) Detailed core description on the archive half of the core will use Dunham's classification.
6) Coral ecology: Identification of the coral species will be undertaken using morphological attributes. In addition, changes in coral community structure will be assessed as sea-water composition changes during the onset of the deglaciation.

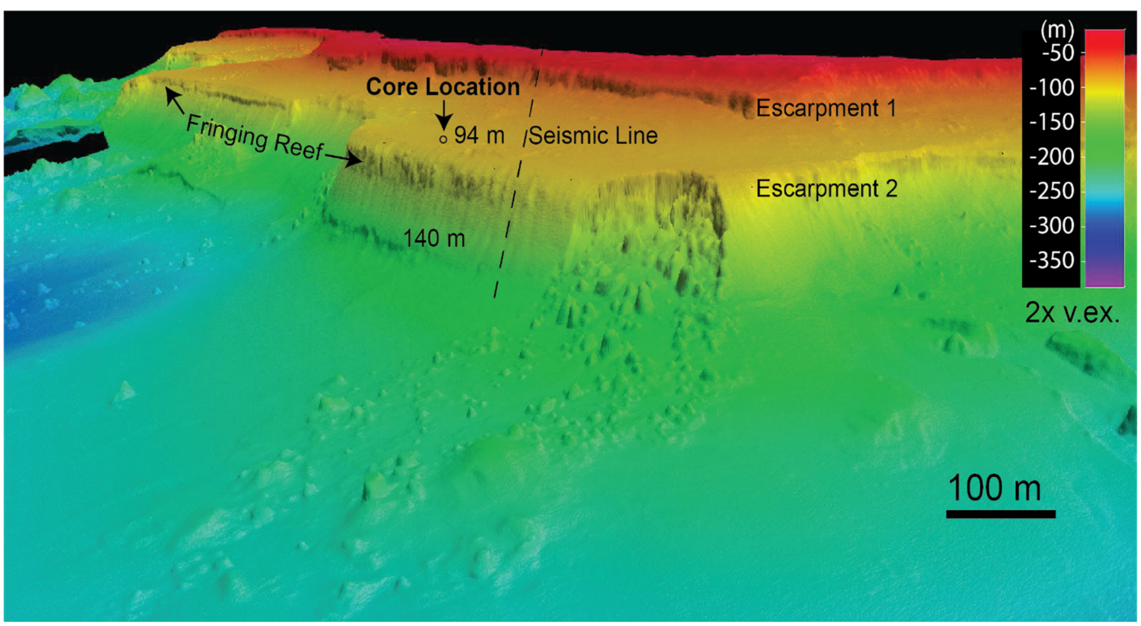

Figure 2: Core location on the fringing reef.

7) Quantitative analysis of core components will be undertaken by identifying textures (i.e. microbial crusts, corals, sediment grains) (Fig. 3) in core and on stitched images. The quantification will be done on adjusted images using Image J's "analyze particles" function.
8) Thin section analysis of petrographic fabrics, diagenetic alterations and grains will be conducted.
9) SEM (scanning electron microscopy) analysis of the microbial crusts and marine diagenetic cements will be undertaken.
10) Age determination using the C-14 method on reef material and crusts will be employed to determine if they grew coevally.
11) Petrophysical studies will be done on 1 inch core plugs that are drilled vertically and horizontally into the working half of the core. Porosity will be measured with a Micromeritics AccuPyc 1330 Helium pycnometer utilizing Boyle's law. Laboratory measurements of acoustic velocity and electrical resistivity measurements will be performed on brine-saturated core plugs under variable pressures using a New England Research Autolab1000 system.
12) Geochemical analyses will consist of 1) stable isotope analysis on regularly spaced samples in each core, 2) XRD of the same samples to determine mineralogy and 3) clumped isotopes to determine the water temperature during reef growth.
13) Results from this research will be compared to previous studies conducted in Tahiti and offshore the Great Barrier Reef. The comparison will include reef composition, coral species ecology, and geochemical signature.

Component	Percentage of Surface Area
Coral	53.6%
Microbialite crust	14.1%
Calcareous coralline algae (CCA)	3.8%
Skeletal rudstone to grainstone	28.5%

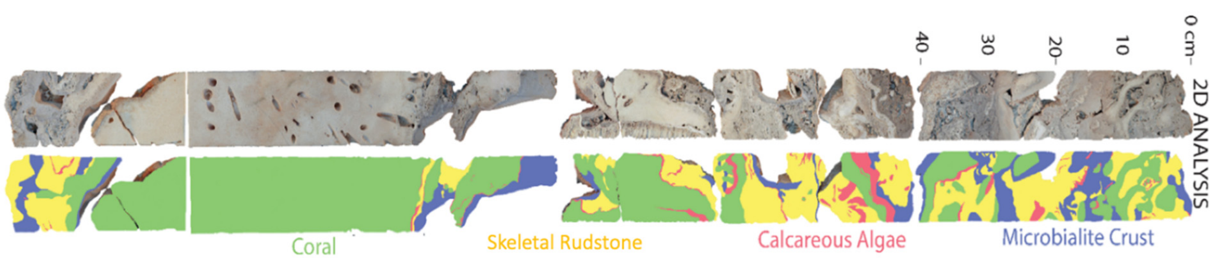

Figure 3: Quantitative analysis of the 2 m core section, displaying the four elements present and their respective abundance.

WORKPLAN

The study of this extensive core material and the large scope of the project will require three to four years to complete. The proposed tasks are arranged in the workplan below; roughly in chronologic order, but once sampling is completed, several investigations will be done simultaneously by different scientists.

Work Plan

Activities

Year 1	Year 2	Year 3	Year 4
Transportation of cores to Miami			
Curation core, cutting, sampling			
Description of Core	Description of Core		
Thin section analysis	Thin section analysis	Thin section analysis	
	Quantitative component analysis	Quantitative component analysis	
	Age determination	Age determination	
	Coral ecology	Coral ecology	
	Geochemical analysis	Geochemical analysis	Geochemical analysis
	Petrophysical studies	Petrophysical studies	Petrophysical studies
		SEM analysis	SEM analysis
			Comparison to other studies
			Final Report/Papers

SIGNIFICANCE

The cores from offshore Mozambique will add a much-anticipated data set for establishing the environmental conditions during the Last Glacial Maximum and the early sea-level rise. In addition, these microbially encrusted coral reefs seem to preferentially grow during deglacial periods. They typically contain large intraframe porosity yet display an extraordinary strength, thus maintaining this porosity to large burial depth. If such microbialite/coral reefs form in a lowstand setting, they could be identified as lowstand reefs on seismic data and are potentially excellent reservoirs.

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OVERFILLING OF ACCOMMODATION IN A MODERN OOID SAND BODY A RECORD OF CLIMATE (STORM FREQUENCY) CHANGE

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2) Department of Marine and Coastal Environmental Science, Texas A&M University at Galveston

PROJECT OBJECTIVES

- Forward the hypothesis that the geomorphology of South Joulter Cay results from punctuated intervals of local hurricane activity impacting hydrodynamic and depositional conditions.
- Suggest a correspondence between island growth stages and periods of elevated storm activity documented from Millennial-scale Atlantic paleo hurricane compilations.
- Given the absence of a local paleo hurricane reconstruction from Northern Andros, the Joulters geomorphology may be informing local activity.

PROJECT RATIONALE

Our ongoing examination of South Joulter Cay, an important component of the large modern ooid sand body lying directly north of Andros Island on Great Bahama Bank, targets a better delineation of the processes and timing that formed the island (Harris and Laya, 2022; Laya and Harris, 2022). High resolution imagery, a DEM constructed from a drone survey, field evidence, and radiocarbon dating of ooids and meteoric cements forward the hypothesis that island geomorphology comprising ridges associated with three distinct island growth stages (Fig. 1) results from punctuated intervals of local hurricane activity over the last ~1800 years.

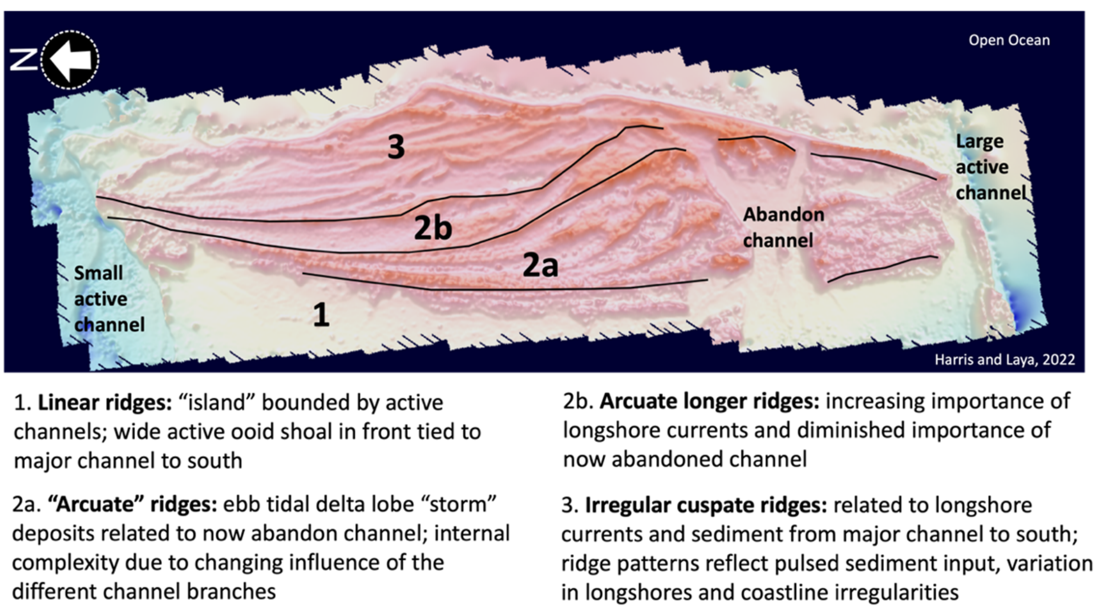

Figure 1: Summary of morphological stages of growth of South Joulter Cay. Annotation shown on DEM constructed from high-resolution drone survey.

Indeed, millennial-scale Atlantic paleo hurricane compilations broadly inform hurricane-climate dynamics, which reveal centennial-scale intervals of elevated Atlantic hurricane activity relative to the instrumental period (Wallace et al., 2019, 2021a and b; Winkler, et al., 2020, 2021, 2023). The scenario for island development summarized on Figure 1 emphasizes active sand bars locally building to beaches and back-beach dune ridges forming repeatedly, with variations in dispersal of ooid sands driven by tidal channels, wind and wave energy, and longshore and storm-related currents. We suggest that intervals of elevated storm activity proximal to Joulters and delivering east to west energy and sediment transport are most likely to have played a role in island development, and radiocarbon dating (Fig. 2), although limited, suggests a correspondence between island growth stages and the periods of elevated storm activity documented from Bahamian storm compilation (Fig. 3). Given the absence of a local paleo hurricane reconstruction from Northern Andros and that local hurricane histories may deviate from basin-wide compilations, the Joulters geomorphology may be informing local paleo hurricane activity.

Figure 2: Satellite image of SJC showing location of samples recently submitted for radiocarbon dating to the Keck Carbon Cycle Ams Facility, Earth System Science Dept, UC Irvine. Separate aragonite ooid and calcite meteoric cement analyses should bracket age of ridge formation (ooid either older than ridge or same age, cement younger and likely still forming). Results improve on those of Harris (1977, 1979) wherein 9 lightly cemented surface rock samples, 4 rock samples collected vertically down a water well, and 8 samples from two rock cores were submitted to the University of Miami Geochronology Laboratory for age determination using a partial ooid dissolution method. Given these were bulk samples of large size (50 mg) so a mixture of diverse ooids and the younger meteoric cement, results must be viewed as a minimum age.

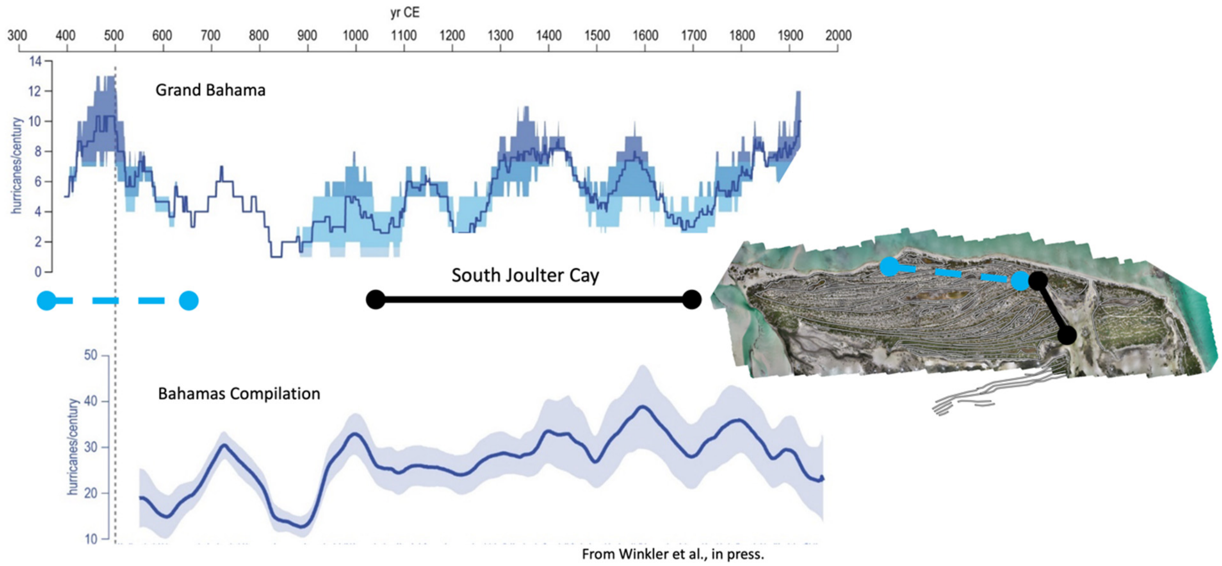

Figure 3: Latest estimates of timing for growth of South Joulter Cay from radiocarbon age dating of marine aragonite ooids and meteoric calcite cements allow for a comparison with paleo-hurricane records, both the latest Bahamas compilation as well as results from the closest site to the northern Andros area – Grand Bahama, derived from studies of cored storm deposits in blue holes from Winkler et al, in press.

SIGNIFICANCE

The scenario proposed here for island growth, an example of the overfilling of accommodation in a Modern ooid sand body, provides insight on the thickening and facies change to be expected locally within a high-energy depostional cycle. The storm aspect of island ridge growth is significant in that infrequent and short-lived events can produce localized "anomalies" that profoundly impact the sedimentary record well beyond the bounds of the island itself, a notion previously put forward by Purkis and Harris (2016) and Harris (2022). As a potential record of local paleo hurricane activity, the Joulters geomorphology may aid in refining the Bahamian storm compilation of others and further our inderstanding of millennial-scale climate change.

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50 YEARS OF RESEARCH ON THE JOULTERS OOID SHOAL: IMPACT ON CARBONATE SEDIMENTOLOGY AND DIAGENESIS AND LESSONS LEARNED FROM AN INVALUABLE ANALOG

Paul (Mitch) Harris

PROJECT OBJECTIVES

- The Joulters sand body is a vast expanse of muddy ooid sands (packstones) rimmed by clean ooid sands (grainstones), which would produce a thin (average thickness 4 m) reservoir layer of significant extent (~400 km^2).
- It's importance as a subsurface analog is considered in this comprehensive review as it illustrates the strike elongated nature of carbonate sand reservoirs relative to the platform margin, lateral heterogeneity that is inherent in such depositional systems and reservoirs due to sand flats and tidal channels, and complexity that is added due to beach/island complexes and their associated diagenesis.
- An understanding of the development of depositional and diagenetic patterns in the Joulters example provides valuable insight to our interpretation of ancient accumulations.

PROJECT RATIONALE

The development of the Joulters sand body (Fig. 1) provides one possible scenario for the evolution of the bar and channel physiography seen in other modern examples. The shoal-generating physiography has been erased, as bar and channel topography were extinguished and filled in, and ooid sands were mixed with other sediments by burrowing. The resulting accumulation – a belt of ooid grainstone bordering a belt of ooid packstone that becomes increasingly muddy with depth – is one that is common in the geologic record. Given its perceived importance, a timely review and discussion of surface sediment distribution, subsurface facies relations, and overprint of early diagenesis, all from the standpoint of Joulters serving as a key subsurface analog, is warranted.

APPROACH

The discussion will: 1) begin with a review of surface depositional environments encountered across the sand body covering surface sediments, details of environments, the importance of islands, change over time, the role of storms, and importance of Hydrodynamics; 2) then emphasize the geologic record of the sand body by detailing facies anatomy and growth, details of the subsurface facies, facies relations in 2D and 3D, the tie to SL and timing, island growth and role of storms, and small-scale facies variation; and 3) finish with a look at diagenesis including marine hardgrounds and beachrock, meteoric island diagenesis, and various cement types and their distribution. Knowledge of the development of the depositional and diagenetic patterns in the Joulters sand body provides insight toward an

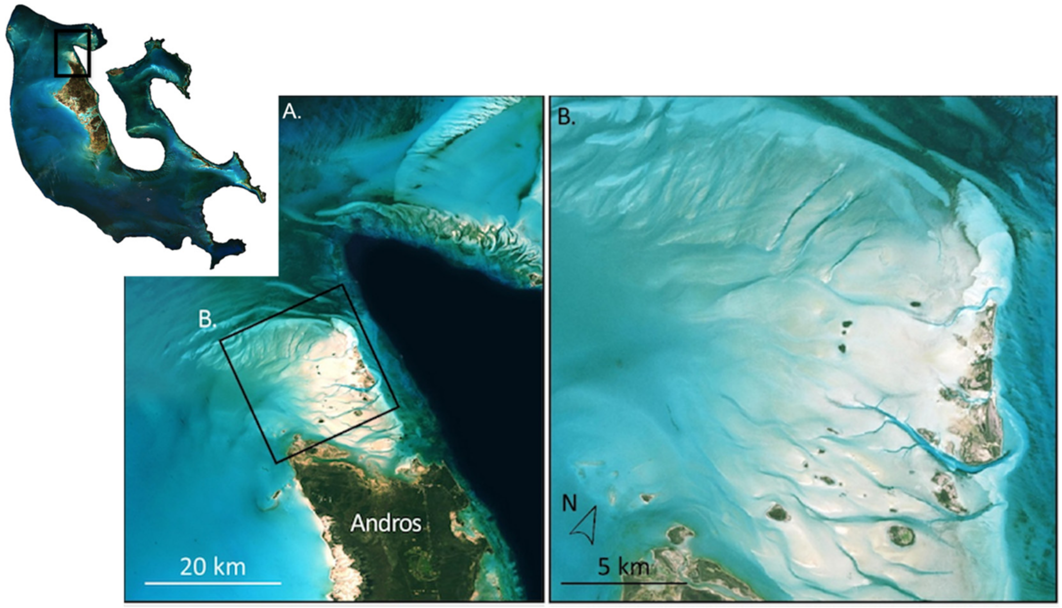

Figure 1: The Joulters sand body sits north of Andros Island on Great Bahama Bank (index and A). Closer view (B) shows details of vast sand flat partially cut by tidal channels and rimmed on the windward margins by active shoals and islands.

interpretation of ancient accumulations. As examples, the following key points will be emphasized:

- Facies calibration
- Facies geometry
- Genesis of upward-shoaling cycle
- Depositional model relative to sea-level change
- Facies preservation
- Subsurface record in 3-D
- Diagenetic overprint and porosity modification

Significance

An understanding of surficial depositional environments and their associated sediments that comes from visiting a modern environment can only sharpen one's eye when faced with trying to interpret rocks on outcrop, in cuttings, or cores. In a similar manner, coring of the modern settings reveals how the facies evolved over time to result in the current depositional and diagenetic patterns and hints at facies and diagenetic relationships that improve one's ability to unravel challenges in subsurface correlation and modelling. It is not an exaggeration that an ooid grainstone/packstone system will be looked at from an entirely different point of view after examining a modern ooid sand shoal like the Joulters example and experiencing first-hand this dynamic landscape and its hydrodynamic setting. The hope is that short of an actual visit to this superb field locality, the review and discussion will serve as a meaningful "virtual field trip" giving an opportunity to appreciate how the many lessons learned from 50 years of research can impact our way of approaching subsurface studies.

RESERVOIR PROPERTIES OF THE APULIA CARBONATE PLATFORM (GARGANO PROMONTORY, ITALY)

Claudia Morabito, Michele Morsilli[1], Ralf J. Weger, and Gregor P. Eberli
[1]Univeristy of Ferrara

PROJECT OBJECTIVES

- Analyze the middle to late Eocene carbonate system of the Apulia Carbonate Platform.
- Conduct Acoustic velocity, Resistivity and Digital image analysis for a reservoir characterization.
- Identify the mineralogy to better understand variations in the petrophysical properties of the measured samples.

PROJECT RATIONALE

Collapse structures and their associated slope gravity deposits are common features of platform margins imaged in seismic sections and multibeam geophysical data as well as in outcrops (e.g. Eberli et al., 1993). Carbonate margin and slope are increasingly being recognized as significant conventional hydrocarbon reservoirs as well (Verwer et al.,2014). Nevertheless, outcrop studies are needed because the details of architecture and textural details of associated gravity deposits are near or below the limit of resolution of geophysical imaging (Lehrmann et al., 2020). The present research project aims to analyze the base-of -slope resedimented gravity flow carbonates belonging to the middle to upper Eocene carbonate system of the Apulia Carbonate Platform, located in the Gargano Promontory, in terms of facies, spatial distribution and depositional architecture.

The carbonate base-of-slope deposits, divided into two main sedimentary models such as apron and carbonate conoids, are little known from the sedimentological point of view, although they are important economically because they can contain large amount of hydrocarbons (Mullins and Cook, 1986). The few systems studied still leave many unanswered questions about what may be the control factors that affect the depositional architecture and the transport mechanisms (Payros and

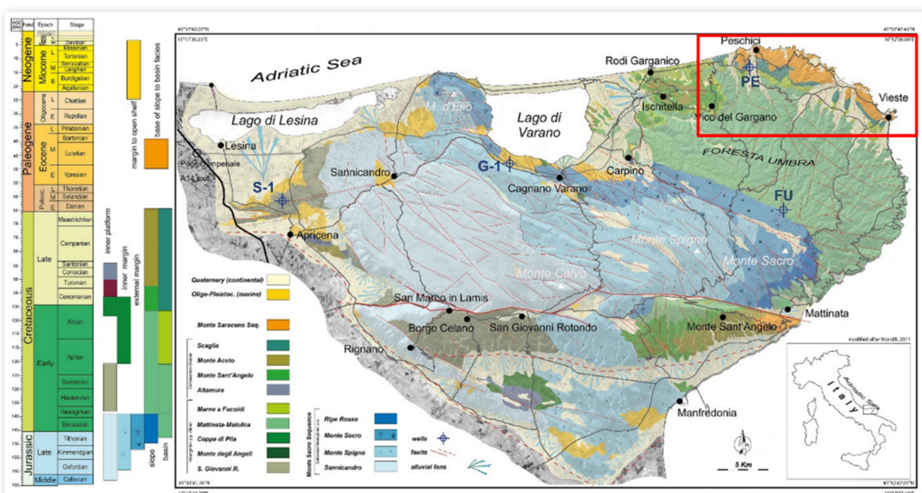

Figure 3: Geological map of the Gargano Promontory (Morsilli et al., 2017). The red box highlights the studied area.

Pujalte, 2008). These still open questions can find answers in detailed sedimentological studies, improving scientific knowledge about such systems in terms of identification and characterization of carbonate reservoirs, since submarine fans form important oil and gas reservoirs around the world.

In addition, slope environments also provide an extensive stratigraphic record that, although it is preserved differently than platform-top or basinal strata, can be utilized to unravel the growth evolution, sediment factories, and intrinsic to extrinsic parameters that control carbonate platform systems (e.g. Verwer et al., 2014). Thus, the focus of this study is to reconstruct the depositional geometries useful to understand re-sedimentation processes, analyze and map the facies present in order to improve the scarce knowledge about these depositional systems, implement the facies models and understand the controlling factors that act during deposition. Finally, the results will be compared with other coeval carbonate systems.

WORK PROPOSED

In order to reach the stated objectives, 54 carbonate rocks from the Gargano Promontory, belonging to the Vieste and Peschici area and from Lutetian-Bartonian in age, will be analyzed. Acoustic velocity and resistivity properties will be measured using the Autolab 1000 system at the CSL. Digital Image Analysis will be performed on thin sections using the method described by Weger et al. (2009) to quantify the pore structures. Mineralogical analysis will be fundamental to better understand the petrophysical properties (sonic velocity, resistivity, porosity) response to the different mineralogies.

SIGNIFICANCE

The analysis of the petrophysical properties (sonic velocity, resistivity, porosity) combined with the mineralogical analysis, will be extremely useful for the reservoir characterization of the Gargano Promontory samples and the further comparison with coeval systems.

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DECODING THE EVOLUTION OF THE LOOP CURRENT-GULF STREAM FROM SEDIMENT DRIFTS

Sara Bashah and Gregor P. Eberli

WORKING HYPOTHESES

- Sediment drifts along the Campeche Bank and the Florida Straits reflect changes in the Loop Current-Gulf Stream circulation patterns through the Neogene.
- Geometry, unconformities, and thickness variation of the sediment drifts archive the current strength, width, and direction along the Campeche Bank and Florida Straits.
- Changes in past climate affected sediment distribution in Campeche Bank and Florida Straits, which is crucial for understanding global teleconnections, feedback thresholds, and forcing mechanisms.

PROJECT RATIONALE

Scientists use geochemical proxies, such as the $\delta^{18}O$ values of benthic foraminifer tests, to decode the timing of paleoclimatic and palaeoceanographic changes. Recent research has shown that the geometry of sediment drifts and unconformities recorded in them can act as physical indicators of palaeoceanographic changes. The formation of sediment drifts results from the actions of bottom currents and can be heavily impacted by current speed, direction, and sediment properties. Although sediment drifts on the Campeche Bank (Hübscher et al., 2023; Lowery et al., 2023) and the Florida Straits (Anselmetti et al., 2000; Bergman, 2005) offer insights into past oceanographic conditions, no stratigraphic correlation exists between the two areas.

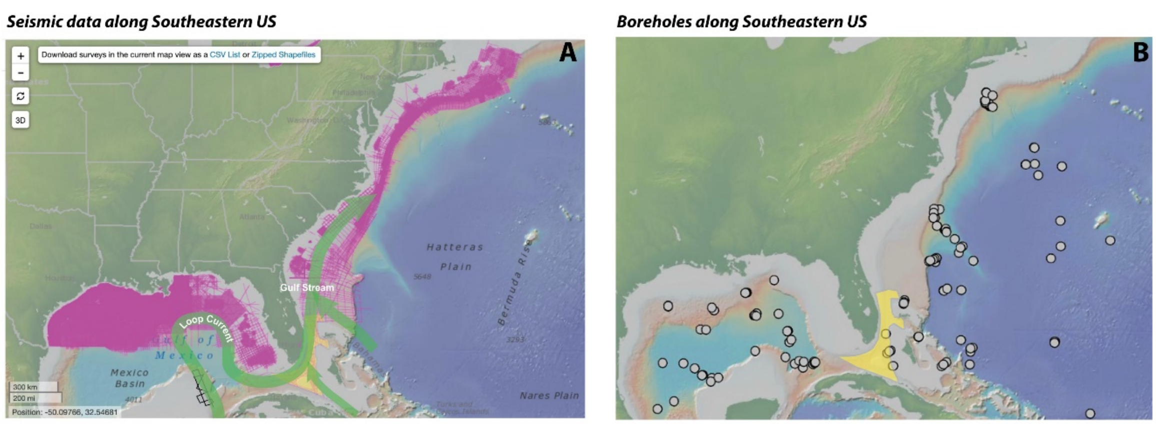

Fig. 1. The map shows A) the location of available seismic data with Loop Current and the Gulf Stream indicated in green and B) boreholes along the Campeche Bank and the Florida Platform, black lines, and yellow polygons indicating past mapped areas.

To address this gap, our study seeks to map and identify the distribution of sediment drifts in these regions and explore the timing and variability of the current processes responsible for their formation. By analyzing sediment drifts geometry, we can track long-term ocean circulation changes, while unconformities indicate abrupt Gulf Stream and Loop Current changes.

DATASETS

The study relies on a robust dataset encompassing multichannel 2D seismic data, well-logs, cores, bathymetric data, oceanographic data, and submersible dives. The seismic data is part of a large data set accessible on the National Archive of Marine Seismic Surveys and the Academic Seismic Portal in areas along the Florida Straits and Campeche Bank, while the core data are from ODP (Fig. 1).

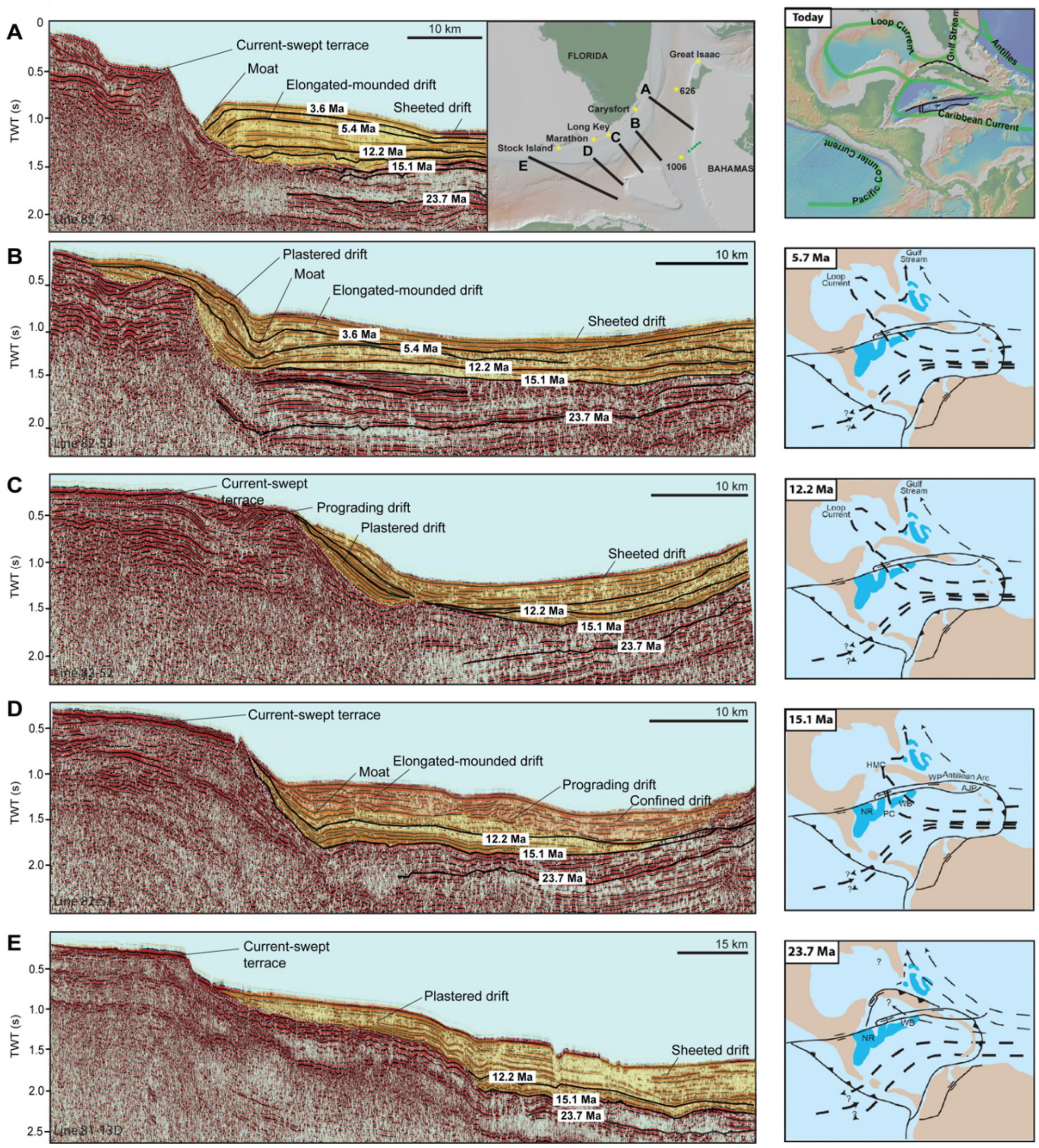

Fig. 2. Evolution of the Pourtales Drift in the Straits of Florida and the tectonic evolution and surface circulation of the Caribbean and Gulf of Mexico (modified from Bergman, 2005).

Workflow

Characterization of bottom current-controlled sedimentary features

The primary objective of this study is to accurately identify and map sedimentary sequences controlled by bottom currents. To achieve this goal, a comprehensive analysis of seismic, bathymetric, sediment cores, and seafloor images will be conducted. The oceanographic data from the World Ocean Database 2018 (Boyer et al., 2018) and available current data will be utilized to establish hydrographic cross-section and temperature-salinity diagrams.

Seismic stratigraphic analysis

The age model from the ODP and IODP cores will be updated to ages from Gradstein et al. (2012). Subsequently, the seismic stratigraphic analysis will be conducted by correlating and generating thickness maps of the study areas to gain insights into phases of ocean current evolution.

Regional and global palaeoceanographic changes

The seismic sequence boundaries within the designated study areas will be assessed considering global sea level changes, paleoceanography, and tectonic events spanning the Neogene to the Present Day (e.g., Fig. 2 and Fig. 3).

Significance

The Gulf Stream plays a critical role in the North Atlantic circulation system, affecting climate, hurricane activity, and sea levels. Recent data shows that the volume transport of the Gulf Stream through the Florida Straits has decreased by 1.2 ± 1.0 Sv in the past 40 years (Piecuch and Beal, 2023). This study aims to provide additional understanding of the evolution of the Loop Current-Gulf Stream system on a geological timescale, which is essential for comprehending global teleconnections, feedback thresholds, and forcing mechanisms.

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FISH DIET IMPACTS THE ROLE OF ICHTHYOCARBONATE IN THE GLOBAL CARBON CYCLE

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PROJECT OBJECTIVE

- Determine how diet impacts ichthyocarbonate production rate and composition through controlled experiments.
- Improve understanding of how ichthyocarbonate contributes to carbon fluxes in the global carbon cycle.

PROJECT RATIONALE

Figure 1: Ichthyocarbonate, observed as white grains on left of image, produced by the Gulf toadfish.

Marine fish are important participants in Earth's global carbon cycle. In their intestine, marine fish produce organic matter and carbonate minerals that are subsequently excreted to the water column. This carbonate, "ichythyocarbonate," is a significant contribution to carbon fluxes in the ocean (Wilson et al., 2009; Saba et al., 2021). New research by our team suggests that the magnitude of ichthyocarbonate production is likely ~4x greater than previously estimated, and the composition of these minerals are anomalous when compared to that produced by other marine calcifiers (Oehlert et al., 2024). Through a stable carbon isotope mass balance, we found that ichthyocarbonate produced by four species of marine fish is enriched in carbon arising from diet (28-56%, but up to 81%) compared to carbonate produced by other marine calcifiers (<10%). Since dietary carbon originates from photosynthetic organisms in the marine food web, the impacts of ichthyocarbonate formation on surface ocean carbonate chemistry may not conform to canonical expectations for net carbon dioxide release from marine calcification. Consequently, it is critical to understand the factors that control ichthyocarbonate production rate and dietary carbon incorporation to quantitatively define the role of ichthyocarbonate in the global carbon cycle.

Fish metabolic rate controls the demand for osmoregulation, the key physiological process responsible for ichthyocarbonate formation, however, the impact of feeding and diet composition on ichthyocarbonate production rate and composition is poorly quantified. In this study, we will report the results of two controlled studies that evaluate: 1) how the feeding state of the Gulf toadfish affects ichthyocarbonate production rate, and 2) how the proximate composition (crude protein, carbohydrate, and dietary fiber) of fish diet impacts dietary carbon incorporation, crystallite morphology, and elemental chemistry of ichthyocarbonate.

Approach

To test the impact of feeding state on ichthyocarbonate production rate, we will collect ichthyocarbonate from fed and unfed Gulf toadfish (*Opsanus beta*), noting the elapsed time between feedings. Samples will be siphoned from the bottom of tanks each day of the experimental period. Wet weight will be measured, and size of ichthyocarbonate will be assessed using ImageJ. Daily production rate will be normalized to fish mass, and statistical tests will be employed to determine whether feeding induces a significant change in ichthyocarbonate production rate. Next, we will conduct a diet switch experiment at the University of Miami Experimental Hatchery to test whether proximate composition of fish diet impacts ichthyocarbonate composition. Ichthyocarbonate produced by the Olive flounder (*Paralichthys olivaceus*) and fed with two diets with different proximate composition will be collected and prepared for analysis of total organic carbon content, stable carbon isotope ratios, crystallite morphology, mol% $MgCO_3$ and phosphorus content.

Significance

Marine fish are currently not incorporated into fully coupled carbon climate models used to model the Earth system, due to knowledge gaps regarding their production magnitude, composition, and fate (Saba et al., 2021). Our research indicates that the role of marine fish in the global carbonate budget is underestimated (Oehlert et al., 2024), and that marine fish contribute significantly to shallow ocean alkalinity cycles (Folkerts et al., 2024). However, lingering uncertainty impacts extrapolation of our findings to the ~13,000 species of marine fish residing in the global oceans. Experiments like those proposed here and others that investigate the influence of fish lifestyle, size, and oceanic conditions on ichthyocarbonate production rates, composition, and fate are critically needed. Consequently, results of this study will reduce uncertainty around the factors that currently preclude the incorporation of marine fish into Earth system models.

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ESTIMATING BLUE CARBON STORAGE POTENTIAL IN EARTH'S REMOTEST ATOLLS

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PROJECT OBJECTIVE

- Quantify the extent of blue carbon ecosystems in ~70 atolls around the world
- Estimate potential carbon stocks in these atolls by leveraging > 30 publications on carbon sequestration in coastal ecosystems

PROJECT RATIONALE

Land use changes and energy demands have resulted in ~2,400 Gt CO_2 of net cumulative CO_2 emissions between 1850-2019 (Lee et al., 2023). As nations seek to mitigate the effects of climate change on decadal to centennial time scales, interest in natural carbon sinks has become an increasingly important focus of research in ecosystem management and climate policy. Several coastal ecosystems, including mangrove forests, salt marshes, and seagrass meadows, are considered natural carbon sinks and widely thought to disproportionately sequester carbon per unit area (Mcleod et al., 2011). Quantitative understanding of the amount of carbon stored in blue carbon ecosystems is currently an area of active research, but global mapping efforts suggest they extend over approximately 2.3 – 7.0 million km^2 (Duarte et al., 2013) and tens to hundreds of Tg C can be buried in these ecosystems annually (Mcleod et al., 2011).

Carbon sequestration by blue carbon ecosystems has been proposed to play a significant role in offsetting national CO_2 emissions in some island nations, like in the Republic of Kiribati and the Bahamas, where carbon-neutrality may be possible (Friess,

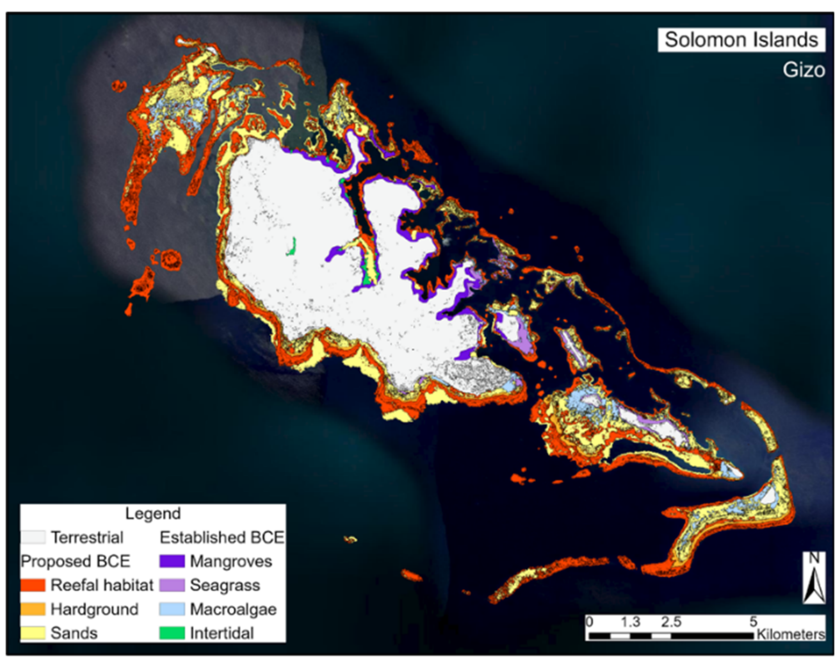

Figure 1: Mapped extent of coastal habitats, including established and proposed blue carbon ecosystems, in the Gizo atoll of the Solomon Islands.

2023). Nature-based strategies for carbon dioxide removal may be particularly important for small island developing states, since they often contain disproportionately high densities of blue carbon ecosystems (Friess, 2023). To properly evaluate carbon dioxide removal by blue carbon ecosystems in these often remote settings, accurate and consistent measurements of carbon sequestration must be conducted globally. Problematically, spatial variability in ecosystem characteristics, insufficient sample sizes, and inconsistent methodology between studies is known to produce significant ranges in potential carbon stocks (Fest et al., 2022) and mapping of small habitat patches on global satellite datasets can be exceedingly challenging (Friess, 2023).

APPROACH

To assess blue carbon sequestration in Earth's remotest atolls, we reanalyzed the high-resolution, globally-resolved, ground-truthed dataset of coastal habitats produced by the Khaled bin Sultan Living Oceans Foundation Global Reef Expedition (Purkis et al., 2019) to generate 69 new maps of blue carbon ecosystem extent. Habitat fragmentation will be assessed on these new maps to support the development of targeted management plans. Leveraging regional and global carbon sequestration rates reported in more than 30 journal articles, we will estimate the potential range of carbon sequestered in these ecosystems, many of which for the first time.

SIGNIFICANCE

The results of this study are anticipated to provide a comprehensive overview of habitat composition, spatial distribution, and associated organic carbon stocks in atolls mapped by the Global Reef Expedition. Of the ~70 atolls investigated, several have never been considered in prior blue carbon budgets, particularly in the Pacific Ocean. Thus, new results will contribute to a more robust baseline understanding of the carbon stocks in blue carbon ecosystems around the world.

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Testing Seal Capacity For Carbon Storage - an Experimental Approach – (Year 2)

Ralf J. Weger, Peter K. Swart, and Gregor P. Eberli

Project Objectives

- Re-Design an experimental set-up that allows for CO_2-Brine saturation prior to CO_2 injection
- Evaluate how the pre saturated CO_2-Brine mixture alters the seal capacity of mixed carbonate-siliciclastic samples.
- Run experiments to assess the amount of dissolution and possible breach of samples.

Project Rationale

Carbon Capture Utilization and Storage (CCUS) will be a crucial component in reducing global CO_2 emissions in the coming years. Although the utilization of the captured CO_2 is an important component, it is likely that carbon capture with permanent storage will play a more important role in achieving faster, large-scale reduction of CO_2 emissions. Permanent storage requires natural reservoirs with a seal that resists dissolution by CO_2 saturated fluids. Many theoretical modeling studies dealing with such rock-fluid interactions have been published in recent years (André et al., 2007; Gaus et al., 2005; Yuan et al. 2019; amongst many others) but actual laboratory experiments are rare. Luquot and Gouze (2009) have shown that CO_2 injection triggered dissolution increased permeability, while inducing only minimal modification of porosity.

Changes in elastic properties resulting from the removal of the smaller particles (i.e., those with highest surface area), the creation of pits of dissolution on the grain surfaces, and changes at grain contacts such as grain welding caused by injection of CO_2 saturated solution have been reported by Vialle and Vanorio (2011).

This project aims to contribute to the experimental side of rock fluid interaction for carbon storage by building on past precipitation/dissolution experiments that we conducted in carbonate rocks (Weger et al., 2012) addressing the potential changes in the seal rocks resulting from CO_2 injections.

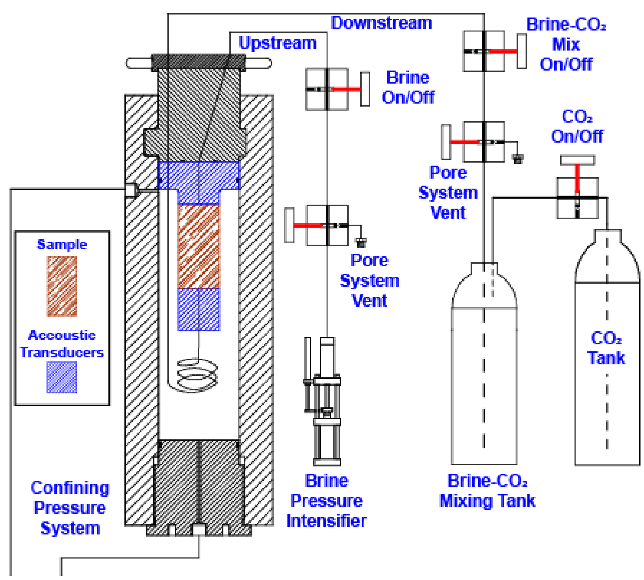

Figure 1: Set-up of proposed dissolution experiments using the Autolab 1000 which allows for pre-CO2-Brine saturation.

WORK PROPOSED

Phase 2 of the project is the design and testing of the experimental setup. The following workflow will be tested first on various rock samples in our New England Research Autolab 1000 system. We will be using a semi-closed system experimental design where pore fluid with predetermined geochemical composition is emplaced in the sample, CO_2 pressure is established, and only the existing fluid volume within the intensifiers (~5-10 pore volumes of the sample) will be used to create flow of fluid within the sample. This limited fluid injection will ensure that any chemical reaction of the fluid with the rock proceeds before the system reaches equilibrium with the host and the chemical reaction halts.

Monitoring of possible reactions that result in dissolution or mineralogy changes is a crucial element in the experiment. We plan to monitor physical changes with time series measurements of velocity. For this, the upstream pore fluid connection is closed. Five MPa pore pressure is installed at 60 MPa confining pressure, resulting in 55 MPa Ep. Time series measurement of VP and VS will be conducted for 72 hours (3 days) taking an acoustic measurement each hour.

After each three-day reaction time, the pore fluid will be extracted and chemically analyzed. In addition, all samples will be examined using SEM and CT scans before and after the experiment.

SIGNIFICANCE

This work will improve our understanding of how rock-fluid interaction changes microstructure and its elastic properties when CO_2 enriched fluids are injected in rocks with seal capacity. The proposed equipment re-design lis expected to produce better results as the previously used method. The quantification and high resolution image documentation of the resulting rock alterations will further enhance our understanding of the rate of changes resulting from CO_2 injection.

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6 months CERTIFICATE PROGRAM
APPLIED CARBONATE GEOLOGY

PURPOSE AND GOALS OF THE CERTIFICATE PROGRAM

The goal of the Certificate Program is to provide first-rate continuing education to professionals or geology students who want to become experts in carbonate geology. To reach this goal courses are offered in carbonate sedimentology, seismic stratigraphy, petrophysics, and geochemistry for an advanced knowledge and understanding of carbonate systems.

OVERVIEW AND COSTS

A Certificate in Applied Carbonate Geology requires the successful completion of 16 course credits assembled from 11 courses in the program (see back). The courses combine classroom teaching, laboratory classes and applied projects. No thesis will be written.
Courses for the Certificate Program will be offered in the Spring Semester and the 1st Summer Session each year. The student/geoscientist will be in residence for 6 months. The current tuition fee is $3,020/credit.

REQUIREMENTS FOR ADMISSION AND REGISTRATION

A bachelor degree or equivalent degree is required but can be offset by years of working experience. No GRE or TOEFL are required. Registration for the Certificate Program started in the summer of 2016 and is handled by the Graduate Studies Office of RSMAS. See also
https://marine-geosciences.earth.miami.edu/academics/certificate-program/index.html

LEARNING OUTCOMES OF THE CERTIFICATE PROGRAM

Learning Outcome 1:

Geoscientists/students will gain a broad knowledge of carbonate geology and geophysics.

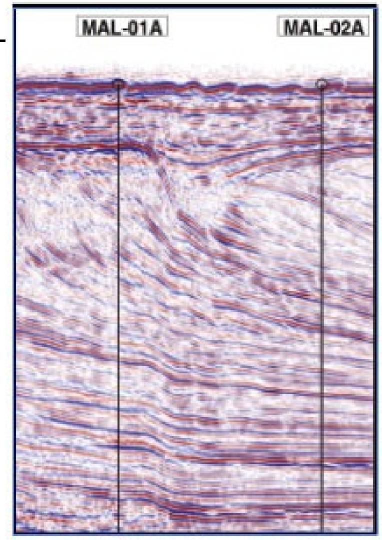
Learning Outcome 2:

Geoscientists/students will learn to incorporate the acquired knowledge and available data and tools into the workflow of applied projects.

Learning Outcome 3:

Geoscientists/students will learn oral and written communication skills and will be able to communicate their ideas and findings to peers, managers, and administrators.

Instructors In The Program



Gregor P. Eberli	Seismic Interpretation of Carbonates
Peter K. Swart	Carbonate Geochemistry
James S. Klaus	Paleoecology, Geomicrobiology
Donald F. McNeill	Sedimentology, Stratigraphy
Ralf J. Weger	Petrophysics
John Dolson	Carbonate Petroleum Geology
Paul M. (Mitch) Harris	Carbonate Geology

Offered Courses

MGS 611 3 Cr Earth Surface Systems

MGS 641 2 Cr Field Evaluation of Fossil Platforms, Margins, and Basins

MGS 601 1 Cr Seminar in MGS

MGS 678 2 Cr Field Seminar: Facies Successions on Great Bahama Bank

MGS 688 2 Cr Field Seminar: Heterogeneity of a Windward Margin

MGS 624 3 Cr Seismic Interpretation of Carbonate Systems

MGS 626 3 Cr Petrophysics of Carbonates

MGS 686 2 Cr Microbial Carbonates

MGS 726 2 Cr Carbonate Diagenesis and Petrography

MGS 627 3 Cr Analysis in Carbonate Cores

MGS 789 2 Cr Petroleum Geology in Carbonates

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