2022

MGU

Michigan Geophysical Union

Annual Symposium Program Booklet

April 7, 2022
University of Michigan
Dept. of Earth and Environmental Sciences
Dept. of Climate and Space Science

Welcome to the 18th Annual Michigan Geophysical Union!

Our welcome message this year is a special one because we are excited to truly welcome everyone back to an in-person MGU event! The world has been a challenging place for the past two years. Research plans were upended by a global pandemic, familiar faces became obscured by masks, and for a time we were forced to move many of our everyday activities online. Though we found ourselves in rapidly-changing and often unfamiliar conditions, as student scientists we persevered. Working remotely taught us that colleagues across continents could be just as close as friends inside our department – often just a video call away. New connections were made and we sought solace in the collaborative processes that are science and engineering.

Like many conferences since 2020, our last conference was held virtually. We filled a digital poster hall with pixelated visitors and shifted interactions to chatrooms and video calls. Live talks were introduced in 2021, although speakers could deliver talks from the comfort of their home office. In short, we made it work! MGU is a space where students present their work in a supportive environment. Several departments come together each year to share ideas and provide new perspectives through their feedback. The success of our symposium hinges on the strength of student presentations that consistently exceed the already high standards of the University of Michigan.

There is something special about chatting with the author in front of their poster. Nuanced conversation and rethinking a hypothesis on the spot is as much a part of our work as experiments and data gathering. MGU is a step on the journey of communicating science and we are proud to bring it back to the physical space!

Welcome back to MGU!

-The MGU 2022 Organizing Committee

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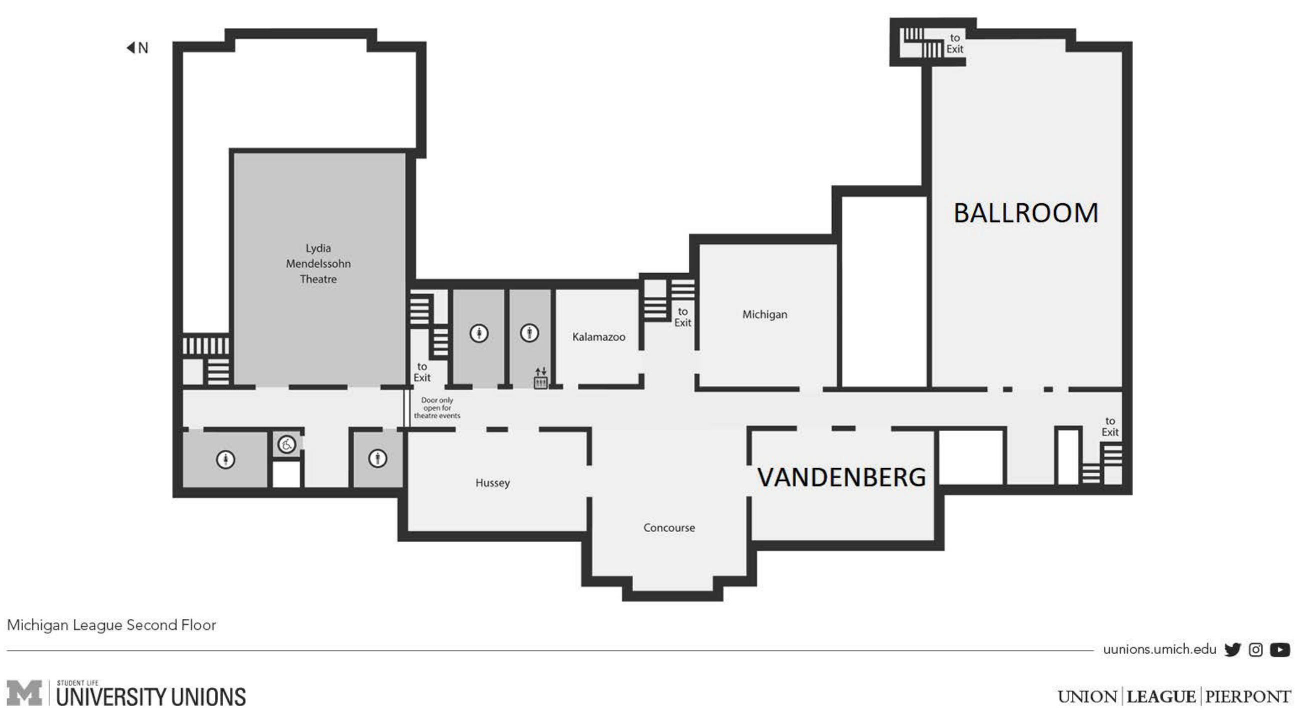

Spatial trends in stable oxygen and hydrogen isotopes of waters in the western United States

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Climate change will continue to impact the availability of freshwater resources in many parts of the world. In the western United States, most communities rely on aquifers and reservoirs recharged from snowmelt as their main source of water. As temperatures increase and snowmelt becomes more variable, it is vital to understand ways to monitor fluxes in catchment amounts. Stable isotope distributions in waters are sensitive to changes in hydrology such as changes from seasonal moisture sources, therefore there is potential to use stable isotopes to track how water resources respond to current and future climate change. This study looks at stable oxygen ($\delta^{18}O$), hydrogen ($\delta^{2}H$), and d-excess values of 94 different water samples including rivers (n = 56), lakes (n = 9), creeks (n = 20), reservoirs (n = 5), and tap water (n = 4) samples with respect to elevation to find trends within states and between states in the western U.S. (namely, Wyoming, Nebraska, Iowa, Utah, Montana, and Idaho).The total range of $\delta^{18}O$ for all 94 samples ranged from -19.2 ‰ to -0.6 ‰ (VSMOW), the total range of $\delta^{2}H$ ranged from -142.3 ‰ to -16.6 ‰ (VSMOW), and the total range of d-excess ranged from -36.2 ‰ to 15.9 ‰ (VSMOW), where the lake and reservoir samples yielded the highest $\delta^{18}O$ and lowest d-excess values. Given previous work on the relationship between stable oxygen and hydrogen isotopes and elevation, we expect a negative correlation with elevation for both $\delta^{18}O$ and $\delta^{2}H$ values. However, we find no correlation with elevation and $\delta^{18}O$ or $\delta^{2}H$ values, instead we find that a majority of the data are consistent with high-altitude precipitation and snowfall. This suggests these water samples originate primarily from high-elevation snowpack. This conclusion confirms previous work in the central Rocky Mountains which found limited correlation between elevation and $\delta^{18}O$ and $\delta^{2}H$, thereby suggesting that isotope composition of surface water in this region reflects the point of recharge into the system. By monitoring isotopes and understanding the trends in $\delta^{18}O$ and $\delta^{2}H$ we will be able to monitor how and if the dynamics of water and recharge change with time for the western U.S.

A comparison of MODIS and tower-based eddy covariance gross primary productivity estimates in the Peruvian Amazon

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In this study, we compared two Gross Primary Productivity (GPP) estimates from MODIS to estimates from two flux tower sites, Quistococha (QFR) and Tambopata (TNR), in the Peruvian Amazon. Using the flux tower data, we calculated GPP directly from available data (24 and 6 months, respectively) by partitioning Net Ecosystem Exchange (NEE) into ecosystem respiration (Rd) and GPP using: $GP\,P = -NEE + Rd$. We also estimated the MODIS GPP using observed Photosynthetically Active Radiation (PAR) from the flux tower data using the MODIS algorithm. Both are compared with GPP from the published MODIS GPP values. The MODIS GPP product can be reproduced with a correlation of 0.834 for Tambopata, and 0.915 for Quistococha, using ground-based measurements for PAR, Temperature, and Vapor Pressure Deficit (VPD), and the MODIS product for fPAR. Based on the direct estimates from the flux tower data, we found that GPP is approximately four times smaller than the MODIS GPP product during the dry season. During the wet season, ground and remotely sensed measurements are more similar, though satellite measurements are still consistently higher. Based on flux tower GPP estimates, we estimate that Tambopata and Quistococha are storing approximately 384 and 1090 g C m−2yr−1, respectively. Based on MODIS estimates, they currently store approximately 2570 and 1900 g C m−2yr−1. If remote products consistently estimate a higher GPP during the dry season than ground-based measurements at other sites, we can achieve better calibration of remote GPP sensors and algorithms to improve the monitoring of rainforest carbon fluxes.

Updates in new Candelaria geochronology and the potential for in situ U-Pb LA-ICP-MS dating of magnetite

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[Not included in DOI at presenting author's request]

How did a mild geomagnetic storm deorbit 40 Starlink satellites?

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This year Thursday, February 3 at 1:13 p.m. EST, Falcon 9 launched 49 Starlink satellites to low Earth orbit at 210km altitude. 40 of the 49 satellites were unable to raise orbit and subsequently were lost due to increased drag caused by a geomagnetic storm event. The quick-look Disturbance Storm Time index (DST) recorded a -69nT minimum disturbance which classifies this event as a mild storm. How could such a weak event cause this much response in the thermosphere? Was there more going on in the magnetosphere ionosphere system at this time which isn't represented in the storm time index? To answer these questions we simulated the event using the Space Weather Modeling Framework in the geospace configuration to take a closer look at the energy dynamics around earth's magnetosphere. We compare with the latest available provisional observations including DST, Auroral Electrojet, and in situ observations and quantify the energy transfer through the magnetosphere and into the ionosphere throughout the event using new analysis techniques.

Investigating plume surface interactions (PSI) on the Moon from the Apollo missions to future lunar missions

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Rocket Plume Surface Interaction (PSI) can eject large amounts of regolith particles, limiting visibility and reducing flight safety. Particles ejected from the surface at high velocities can damage spacecraft, its instruments, and surrounding hardware. We have learned from Apollo missions that the mean time to failure of a system can be significantly reduced by the presence of lunar dust on materials and mechanisms. Upcoming lander missions are expected to force dust transport across the Moon whenever a lander's rocket plume impinges on the surface, causing erosion and ejecting particles at high speeds. As a result, this interaction poses multiple risks to future lunar exploration missions, especially for astronauts. Thus, understanding PSI processes is paramount to the safety of the lunar exploration program. In order to better understand PSI, we are developing in-flight instrumentation and conducting ground tests to assess the PSI effects. The Saltation sensor (SALT) is one of the instruments to be used for this application. SALT was originally developed to measure energy flux of saltating particles on the surface of Mars. We are now working on modifying this instrument to function as a PSI instrument for lunar applications to collect data during descent and landing. SALT will be designed to quantify PSI effects in the actual lunar environment for the first time ever. Since PSI is poorly known and these instruments are first of a kind, it is necessary to calculate estimates of parameters such as particle concentration, velocity range of ejected particles, energy of impacts, and more, to assess the requirements of the instrumentation. These estimates have been derived using various methods along with analysis of Apollo lunar data. The results demonstrate that ejected particles will be able to travel distances up to 160 km away from the landing site with velocities up to 1200 m/s. The ejected particles could cause significant damage to nearby hardware and could affect surface equipment more than 100 km away. Our estimates are being used to derive the requirements for the PSI instruments. These instruments will help advance lunar science by providing the scientific community with observational data regarding particle movement to inform lander providers, such as CLPS (Commercial Lunar Payload Services) of potential risks to their vehicles during landings due to PSI effects. Our results can be used to improve prediction capabilities and develop mitigation strategies for future missions. This is crucial in ensuring safety during landings on the Moon.

Using isotope-enabled climate models to analyze orbitally driven oxygen isotope variability in the PETM

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Periods of extreme warmth and elevated atmospheric CO_2 levels, like the Paleocene-Eocene Thermal Maximum (PETM, ~55 million years ago), are often used as an analog for future climate change. Paleoclimate reconstructions of the PETM can provide important data constraints on the climate and hydrological cycle under extreme warm conditions. Available terrestrial oxygen and hydrogen isotope records of the PETM have been primarily interpreted as the enhanced hydrological cycle associated with the large-scale warming induced by the high atmospheric CO_2. However, the orbital-scale variations in these isotope records have been difficult to quantify and largely overlooked, even though orbital changes can contribute to the distribution of solar irradiance and therefore impact warming and the hydrological cycle. In this study, we plan to fill this gap through tracking oxygen isotope ratios within precipitation ($\delta^{18}O_p$) and investigating if potential orbitally driven $\delta^{18}O_p$ differences explain variability in the proxy record. We conducted a suite of fully coupled, isotope-enabled Community Earth System Model (CESM1.2) simulations of the PETM with various atmospheric CO_2 levels and orbital configurations. The PETM simulations include cases of 3x and 6x preindustrial CO_2 values (~285 ppm), with each case including 4 orbital sensitivity runs: modern orbital configuration, maximum Northern Hemisphere seasonality, maximum Southern Hemisphere seasonality, and minimum global seasonality in solar insolation. By examining the $\delta^{18}O_p$ differences between these runs, we find that the modeled variability in $\delta^{18}O_p$, accounting for seasonality, largely captures proxy variability. Our results also indicate that the relative impact of orbit and CO_2 on global average $\delta^{18}O_p$ change with season, whereas orbital changes have a greater impact in the Northern Hemisphere summer season and CO_2 changes have a greater impact in the fall and spring seasons. Finally, accounting for seasonal range, the modeled case of 6x CO_2 and maximum Northern Hemisphere insolation seasonality best matches the proxy records we used. Our conclusions consider relevant background into the proxy record, including the preservation state of the proxy, analytical uncertainty, and the relationship between $\delta^{18}O_p$ and environmental context, and illustrates the significance of fully coupled, isotope-enabled climate models when interpreting proxy records in times of extreme warmth.

Potential sulfur substitution mechanisms into apatite: natural examples vs. metasomatism experiments at 1000 MPa and 800 °C

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[Not included in DOI at presenting author's request]

Quantifying XRF core scanning counts within different sediment matrices: transitioning from a nearshore to farshore environment at IODP site U1553

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XRF scanning data provides high resolution nondestructive elemental records of sediment cores for paleoceanographic reconstruction. Yet, many factors (i.e. water content, grain size, core matrix etc) complicate this semi-quantitative data, making comparisons of elemental data between cores and core scanning facilities difficult and interpretations uncertain. Studies attempting to resolve these complications by comparing XRF scans between multiple labs, found that log ratios of elemental data provided more robust data comparison than either raw element counts or linear ratios. Here we investigate how changes in core matrix and sediment provenance impact correlations between semi-quantitative XRF scans and quantitative ICP elemental analysis. To determine which elemental ratios can effectively quantify XRF scans we conducted statistical tests of multiple elements on four sediment facies at IODP Site U1553. The 581.16m long sediment core collected south of New Zealand (52°13.44'S:166°11.49'E) at 1221m water depth, spans the Oligocene to the early Paleogene and consists of 5 units, transitioning from nannofossil ooze, through chalk, to limestone, and finally mudstone and sandstone. 280 samples analyzed by ICP-MS at the Michigan Elemental Analysis Lab at the University of Michigan were combined with 72 shipboard ICP-OES analyses to generate quantitative elemental concentrations. Within the carbonate units, detrital element concentrations are diluted. When carbonate elements (e.g., Ca, Sr) are used as a denominator for log-ratios, the calibration curve (XRF vs. ICP) r^2 values are high for the elements affiliated with aluminosilicate sediments (e.g., Si, Al, Ti, K, Fe, Zr). Yet when the aluminosilicate elements are used as a denominator in the log-ratio calibration curves, the r^2 values are low due to the low signal to noise ratio of the aluminosilicate elements. Even with low r^2 values, the calibrated points on the downcore profiles broadly match the ICP concentrations such that high and low elemental concentrations can be differentiated. Careful consideration of signal to noise ratios can refine interpretations of XRF core scans, improving understanding of the environmental conditions in which the sediments were deposited.

To clean or not to clean: Influence of cleaning procedure on trace element-to-calcium ratios measured in foraminiferal calcite

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Measurement of trace- and minor-elements in the tests of fossil foraminifera using solution-based ICP-MS is one of the most effective methods for reconstructing past ocean conditions. Foraminiferal calcite must be cleaned prior to analysis, as such samples are often impacted by post-depositional diagenesis (e.g., through the presence of a contaminant adhering to the test's exterior) which can impact paleoclimate interpretations. Choosing which cleaning procedures to include or omit in the preparation of foraminiferal samples is challenging. With too few steps, there is a risk of not removing diagenetic signals in their entirety. However, with too many steps, there is increased risk of sample loss due to additional chemical and physical interactions (either through premature dissolution or physical breakdown of fragile test fragments). In this work we present findings for the influence of six different cleaning procedure steps on measured element to calcium ratios (Li/Ca, Na/Ca, Mg/Ca, Al/Ca, Mn/Ca, Fe/Ca, Zn/Ca, Sr/Ca, Cd/Ca, I/Ca, Ba/Ca, and U/Ca) in two species of foraminifera from endmember depositional environments. Our data suggest that element response to cleaning procedure steps can be categorized into 4 groups: elements that are most sensitive to clay removal, elements that are most sensitive to reductive/oxidative cleaning, elements that are relatively invariant to cleaning procedure, and elements that become enriched with increased cleaning steps. When choosing a cleaning procedure, paleoceanographers must think about their desired analyte, whether the recommended sample preparation strategy for that analyte is compatible with other elements of interest, and whether or not the analyte is likely to be present in a contaminant phase in the depositional environment. With this information, we make recommendations for requisite procedural steps to include in the preparation and cleaning of foraminiferal calcite samples based on desired elemental analytes and site/sedimentary characteristics.

Using mercury stable isotopes to identify sources of methylmercury to aquatic food webs

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[Not included in DOI at presenting author's request]

Investigation of biomineralization processes in Maastrichtian age (69–66 Ma) Antarctic bivalves using bulk stable and clumped isotopes

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The bulk stable isotope ($\delta^{18}O$ and $\delta^{13}C$) and clumped isotope (Δ_{47}) composition of fossil bivalve shells are commonly used paleoenvironmental proxies. While the outer shell layer is widely shown to record environmental information faithfully, the inner shell layer is less well studied and may be more susceptible to biologically induced fractionations (vital effects) due to its isolation from inhabited water. Vital effects have been observed in bivalves and other taxa for many decades, but it has historically been difficult to track the timing of isotopic fractionations and link them to causal mechanisms in the fossil record. Here, we integrate measurements of $\delta^{18}O$, $\delta^{13}C$, and Δ_{47} from five bivalve genera (*Lahillia, Dozyia, Eselaevitrigonia, Nordenskjoldia*, and *Cucullaea*) from the Maastrichtian (69–66 Ma) of Seymour Island, Antarctica to isolate fractionations occurring during two major phases of shell formation: the precipitation phase and the extrapallial fluid formation phase. We find that isotope values in the outer shell layers are consistent across taxa and likely represent an environmental signal, but the inner shell layers record a variety of taxon-specific vital effects. Paired Δ_{47} and $\delta^{18}O$ measurements indicate that isotope values from the inner shell layers of *Lahillia* and *Cucullaea* record kinetic fractionations that likely occurred during the precipitation phase. The inner shell layer of *Nordenskjoldia* appears to have precipitated in equilibrium with extrapallial fluid, but remaining offsets from the $\delta^{18}O$ and $\delta^{13}C$ values of the outer shell layer indicate that the isotopic composition of the inner extrapallial fluid was fractionated from inhabited water during the EPF formation phase. Our results demonstrate that clumped isotope measurements can be useful in identifying certain kinds of vital effects in bivalves, and that the synthesis of isotope geochemistry and paleophysiology can illuminate aspects of the biomineralization process in deep time.

Using airborne observations over the U.S. corn belt to quantify N_2O emissions and evaluate underlying controlling processes

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Nitrous oxide (N_2O) is the third most important anthropogenic, long-lived greenhouse gas as well as currently being the most important stratospheric ozone depleting substance emitted as a result of human activities. The main source of anthropogenic N_2O emissions are agricultural soils, where excess nitrogen applied as fertilizer can escape to the atmosphere as this potent greenhouse gas. The processes that govern these emissions are complex and highly heterogeneous in space and time, presenting a measurement challenge. Different weather and farming practices impact N_2O emissions, and if these controls are understood, practices could be optimally designed to minimize climate impacts. Here we look to overcome historical challenges to observe N_2O emissions at spatial scales from ~1–100 km. We use airborne measurements and an atmospheric transport model to evaluate emissions at single to many farms spatial scale and assess the impact of different environmental factors on emissions. We will present observations from the Measurement of Agriculture Investigating farm-Zone Emissions of N_2O (MAIZE-2021) campaign. MAIZE-2021 conducted a series of flights (10 flights) totaling approximately 50–60 hours in Spring/Summer of 2021. These flights targeted regions of corn and soybean production in Central and Western Iowa as well as Eastern Nebraska. Flights were designed to quantify emissions from ~1–100 km. We will discuss emissions of N_2O over these domains as quantified by airborne mass balance methods as well as inferred from inverse modeling supported by a Lagrangian Particle Dispersion Model. Further, we will assess the relationship between emissions and environmental factors such as crop type, soil moisture, and temperature.

Reconstructing ocean temperatures from a new K-Pg Boundary Section using clumped isotopes

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Studying past climate can help us understand how past CO_2 relates to global warming and how organisms respond to a changing climate. To study mass extinctions, we must know what Earth was like before and after the extinction. We can uncover a baseline climate from before the end-Cretaceous Chicxalub impact and mass extinction through studying the chemistry of fossil shells collected from specific locations that span this boundary. In this project, we aim to determine ocean temperatures from the Cretaceous Gulf Coastal Plain during the Maastrichtian (72.1 to 66 Mya). We collected marine fossils from this time from anew K-Pg boundary site called Ellis Sand Pit (ESP) in Mississippi. We collected shells from 4 layers at ESP and analyzed 1 sample from each horizon for preservation under a scanning electron microscope (SEM). We chose at least 2 samples from each layer and powdered them, then measured the powder for clumped isotopes (Δ_{47}) and stable oxygen and carbon isotopes ($\delta^{18}O$, $\delta^{13}C$). We then used the clumped isotope data to calculate ocean temperaturesand combined this with shell $\delta^{18}O$ to determine the oxygen isotopic composition of seawater ($\delta^{18}O_{sw}$). Mean ocean temperatures ranged from 17 to 29 °C with good agreement between 2 measured samples from each horizon and mean $\delta^{18}O_{sw}$ was 0.21 ± 0.83 ‰ (1sd) on average. This new data will be compared to reconstructed temperatures from other K-Pg boundary sites near ESP that have existing clumped isotope data and to modern analog environments.

Combining snapshots of the past and present: does the use of extant and extinct data change our understanding of how mass extinctions alter diversification dynamics?

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The Cretaceous–Paleogene (K-Pg) mass extinction that occurred 66 million years ago had a profound influence on shaping patterns of modern biodiversity. This mass extinction eradicated many dominant lineages on Earth which triggered rapid morphological and lineage diversification of surviving groups. Perspectives on these radiations derive either from observing changes in taxonomic diversity in the fossil record or from reconstructing the evolutionary history of a group using extant (living) species and molecular time-calibrated phylogenies. However, the "extinct only" and "extant only" approaches represent incomplete snapshots of biodiversity whereas integrating fossils into a phylogenetic framework has to potential to yield more accurate macroevolutionary inferences. Carangaria, a large group of morphologically diverse fishes including flatfishes, marlin, and jacks, underwent a rapid diversification event immediately after the K-Pg extinction. Despite the rich fossil record available for Carangaria, this finding stems from molecular data alone and fossils have never been used to constrain rates or modes of morphological diversification in this group. In this study, we will test whether incorporation of fossil data into an extant phylogenetic framework supports or contradicts the reported burst of morphological diversification in Carangaria. This study has bearings on models of evolutionary recovery among fishes after the K-Pg extinction, as well as more general implications for the role of fossil data in overturning or amplifying conclusions drawn from living species alone.

Triple oxygen isotope analysis of phosphatic biominerals

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Renewed interest in the triple oxygen isotope system and recent improvements in analytical precision have enabled Earth scientists to routinely measure ^{17}O content of natural materials such as waters and carbonate minerals, but triple oxygen isotope measurements have historically been difficult to make on materials where oxygen is phosphate bound. This limitation inhibits triple oxygen measurements of many biogenic phosphatic materials (e.g. skeletal apatite) that may serve as valuable paleoenvironmental and paleoecological records. Here, we present methods that yield high precision triple oxygen isotope measurements of phosphates. To achieve this, we adapted methods commonly used to measure phosphate $\delta^{18}O$ and married them to existing methods of triple oxygen analysis. This requires extensive front-end sample preparation, where samples are dissolved and the phosphate portion is reprecipitated as silver phosphate for analysis. The phosphate bound oxygen is then converted to carbon monoxide via thermal conversion in a furnace at 1420 °C. Subsequent methanation and fluorination of the sample gas ultimately yields diatomic oxygen which is analyzed via dual-inlet isotope ratio mass spectrometry. Measurements of phosphate standard reference materials suggest that the typical analytical precision of this method is between 5 and 10 parts per million, approximately a four-fold increase in precision from comparable methods (e.g. direct laser fluorination).

A new paleotropical marine fish bearing horizon dating to the Latest Danian Event (LDE—62.2 Ma) of the Eastern Desert, Egypt

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The Cretaceous-Paleogene (K-Pg) mass extinction event resulted in apparent origination and diversification of several vertebrate clades that dramatically reconstructed faunal composition in terrestrial and marine environments. Among vertebrates, this led to the dominance of mammals in the terrestrial environments and the acanthomorph (spiny rayed) fishes in the marine realm. However, the scant body fossil record for the latter in the early part of the Paleocene hinders our understanding of faunal turnover. The acanthomorph fossil record from the Danian is sparse, being limited to a handful of sites worldwide. Here, we report a new diverse marine fish assemblage associated with the Late Danian Event (LDE) horizon, a hyperthermal dated to 62.2 Ma, in the top part of the Dakhla Formation in Gebel Qreiya in the Eastern Desert of Egypt. Most of the fossils are articulated and derived from the dark laminated marl at the base of the LDE layers that were deposited in an outer neritic to upper bathyal setting (150–250 m). The Gebel Qreiya assemblage yields representatives of lineages that originated before the K-Pg and survived the extinction event, including extant clades (syngnathiforms and clupeiforms) and a late surviving example of a marine neopterygian fish (pycnodontiforms) that would go extinct by the end of the Eocene. These survivors are joined by well-known Paleogene radiations (Carangiformes) and several percomorph morphotypes resembling Eocene forms, and a peculiar and as yet undetermined acanthomorphs might represent short-lived groups. The Gebel Qreiya assemblage marks the first record of Carangiformes with fossils belonging to two lineages: Menidae and Carangidae. These fossils predate the earliest previous occurrences for the families by roughly 5 million years. This will likely have consequences for inferred evolutionary timescales for these groups. In addition to filling a critical stratigraphic gap with important consequences for models of turnover associated with the K-Pg, the Gebel Qreiya fauna provides a rare glimpse of articulated early Paleogene marine fishes at low latitudes.

Integrated O, Fe, And Ti isotopic analysis elucidates multiple metal and fluid sources for magnetite from the Ernest Henry IOCG Deposit, Queensland, Australia

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Taphonomic aspects of a Permo-Carboniferous fish assemblage from southern Brazil

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The Permo-Carboniferous (Bashkirian-Kungurian) Lontras Shale in Brazil is regarded a Konservat-Lagerstätte due to the exceptional preservation of its fauna, especially invertebrates (e.g. sponges, arthropods) and fishes. This unit represents the uppermost portion of the Campo Mourão Formation and was deposited in a restricted marine environment during a deglaciation event, as interpreted from its unique faunal composition and indication of anoxic events. Taphonomic studies dealing with the invertebrate fauna have demonstrated a wide range of modes of preservation (e.g. carbonaceous compressions, phosphatization), including hard and soft parts. However, despite the abundance of fish fossils in this unit, little is known about the taphonomy of this assemblage. In this work I describe the taphonomic aspects of this fossil fish assemblage, considering both flattened and three-dimensional (3-D) specimens distributed through the 1-meter-tall macro-fossiliferous unit. Through examination of specimens with a microscope and CT-scanning it was possible to distinguish diverse modes of preservation of 3-D and flattened specimens. 3D specimens found in concretions tend to be preserved as phosphatized remains or be very similar in density and superficial aspect to the surrounding phosphatic matrix. The most distinguishable feature of these specimens is the presence/absence of infill within the fish and the degree to which there is recrystallization on phosphates and presence of pyrite micro-crystals on the surface of bones. However, there is a spectrum of these changes in infill and recrystallization, which are found in many degrees among the analyzed specimens. Flattened specimens are mainly preserved as phosphate sheets of similar color to the surrounding black shales and on some occasions by heavily recrystallized bone covered in a thin sheet of pyrite-like material. Flattened specimens also vary in the degree of articulation of the skeleton, from complete/almost complete specimens to heavily disarticulated specimens and isolated bones. Preservation of flattened specimens is consistent with previous work on co-occurring invertebrates, but fishes provide a better example of variation in the degree of articulation, which can be used as a proxy for transportation and determining time before burial. On the other hand, 3-D specimens show new fossil diagenesis information for the locality, indicating a large influence of diagenetic modification after final burial, which is not reported for the invertebrate fossils from this locality. Additionally, loose concretions containing 3-D specimens provide information on weathering and dissolution of rocky matrix and fossil remains. Thus, the fossil fish assemblage from the Lontras Shale provides novel information on the fossil diagenesis in the locality, which complements information from invertebrate fossils and has the potential to refine local paleoenvironment interpretations.

New estimations of relative magnitudes and magnitude frequency distribution for an induced earthquake sequence

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Unconventional oil recovery processes such as hydraulic fracturing and wastewater injection lead to induced seismicity and a constantly changing environment of stress conditions that affect the seismic hazard in a region. To understand the evolving hazards of induced seismicity, we must first determine the Magnitude Frequency Distribution (MFD) and obtain estimates for the Gutenberg-Richter b-value. Recently, it has been proposed that variations in b-value may also be used to discriminate between large foreshocks and the mainshock of a tectonic earthquake sequence, though this has not yet been applied to induced sequences. any regions that have experienced a dramatic rise induced seismicity since ~2009 lack widespread instrumental coverage to monitor this seismicity. Thus, some parameters such as earthquake magnitude (of which the MFD relies heavily on) are not estimated adequately. We attempt to improve the quality of hazard assessment for the 2011 Prague, Oklahoma sequence. First, we re-estimate the earthquake magnitudes using a relative magnitude method that compares waveform amplitudes between pairs of individual events. Then we monitor the spatial and temporal variations in the MFD using a newly published method for determining b-value, called b+ which utilizes the differences between magnitudes of successive events. Finally, we compare the performance of the relative magnitude and b+ methods against traditional b-value estimation. We find that the relative magnitude method is a convenient method to determine magnitude relationships where current magnitude estimates may be unreliable. We also find that the b+ method yields a more stable estimate of the b-value compared to traditional methods. Finally, we determine that there is a reduction in b-value immediately before the mainshock and we note that b+ does not return to background levels for ~2 years after the mainshock. Overall, we present updated estimates for MFD and b-values which will provide new knowledge of the evolving hazards associated with the Prague sequence, and guidance for future understanding of the seismic hazards associated with injection processes.

Reconstructing marine temperatures and seasonality on the Plio-Pleistocene Florida Platform: assessment of a regional mass extinction

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Exposures of fossil-rich shallow marine deposits in southwestern Florida illustrate that a regional mass extinction event occurred on the drowned Florida Platform over the course of the Late Pliocene to the Early Pleistocene. Cooling water temperatures in the region have been invoked as a driver of this extinction event, yet exactly how water temperatures evolved over this period remains largely unclear. In this project, we will use clumped isotope sclerochronology to quantitatively reconstruct long-term and seasonal-scale marine temperature variability on the Plio-Pleistocene Florida Platform in order to assess the potential role of temperature change as a driver of the extinction event. In the process, we will also generate groundbreaking new data regarding the dynamic hydrology and unique paleoecology of a submerged Florida Platform environment. Here we present preliminary analyses of fossil shells collected from the Early Pleistocene Caloosahatchee Fm. (post-extinction; ~2.0–1.6 Ma).

Insights into the formation of the New Afton Cu-Au porphyry deposit, Kamloops, Canada from magnetite textures and chemistry

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New Afton is an alkalic porphyry Cu-Au mineral deposit hosted in monzonite stocks that intruded mafic volcanics in the Mesozoic Quesnel Island arc terrane, Western Canada. Theore-forming magmatic-hydrothermal fluids evolved from the intrusions and precipitated sulfide minerals and native gold as disseminations and veinlets at the brecciated margins of the stocks. The sulfide assemblage is dominated by chalcopyrite and pyrite with lesser amounts of bornite. Magnetite and hematite are spatially associated with the ore minerals and are widely distributed throughout the deposit. Magnetite occurs as massive aggregates in lodes, infill in veinlets, and disseminated crystals. Here we contribute to the understanding of mineralization at New Afton byinvestigating the compositions and textures of magnetite. Magnetite-bearing samples were selected from representative drill core and analyzed via scanning electron microscope (SEM) and electron probe micro-analyser (EPMA). Crystallization temperatures for magnetite were calculated by using the Mg-in-magnetite geothermometer. Two types of magnetite were identified. Magnetite 1 is found in veinlets and disseminated in the host rock groundmass; it consists of coarse crystals containing ilmenite/titanite exsolution lamellae, usually displaying euhedral and mosaic-like texture. Magnetite 2is medium to coarse-grained, contains mineral inclusions, lacks exsolution lamellae, and dominantly consists of anhedral to euhedral crystals that are commonly intergrown with actinolite and apatite; it is typically observed in massive lodes as well as in veinlets. Both magnetite types underwent partial to complete replacement by hematite and minor chalcopyrite. Magnetite 1 average concentrations of Ti, Mn, and Ni are 0.7, 0.4, and 0.004 wt.%. In contrast, magnetite 2 exhibits lower concentrations of Ti (0.2 wt.%) and Mn (0.1 wt.%) and higher values of Ni (0.04 wt.%). Temperature ranges are slightly higher for magnetite 1 (530-580 °C) than magnetite 2 (480-550 °C). Textural observations of mineral assemblages, magnetite compositions and model temperatures reveal two main stages of magnetite crystallization. Magnetite 1 precipitated from a magmatic-hydrothermal fluid at temperatures where the solubilities of chalcopyrite, pyrite and bornite remained high and those phasesdid not precipitate. Magnetite 2 precipitated from a second magmatic-hydrothermal fluid over the temperature range where chalcopyrite, pyrite and bornite saturation was reached and those phases co- precipitated with the second generation of magnetite. Disproportionation of SO_2 in the second fluid during cooling below 550 °C would have triggered the precipitation of chalcopyrite by reaction of a Cu-bearing fluid with magnetite and concomitant oxidation of magnetite to hematite. The data and interpretations reported here suggest that early magnetite may create favorable conditions for subsequent sulfide mineralization.

Dietary paleoecology of ungulates from the Miocene Dove Spring Formation, southern California

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The fossil record allows for investigations into the effects of environmental change on mammalian diversification over geologic time. The middle Miocene (ca. 14 Ma) is associated with tectonic episodes that significantly altered the topography of western North America. Landscape changes contributed to the contraction of closed-canopy habitats and expansion of the grassland biome throughout North America and other parts of the world. Communities of mammals adapted to these changes by evolving feeding ecologies that exploited new vegetation resources. Here we focus on the dietary ecology of hoofed mammals (ungulates) from the Dove Spring Formation (12.5–9.5 Ma) located in the Mojave region of southern California. We described paleoecology at the community and family levels, and relate these changes to intervals of tectonic activity. Using carbon-13, we analyzed three ungulate families (Antilocapridae, Camelidae, and Equidae) at half-million year time intervals within the 4-million-year sequence. Carbon isotopes of herbivore tooth enamel track the photosynthetic pathway of plants consumed, with depleted $\delta^{13}C$ values indicative of C3 plants and closed-canopy habitats, while enriched $\delta^{13}C$ values indicate an increase in open grassland habitat. C3 vegetation exists on a spectrum of $\delta^{13}C$ values from -37 to -20 ‰, which is offset by about +14‰ in tooth enamel. A previous study concluded that herbivores in the Dove Spring Fm. had diets consisting exclusively of C3 plants, but did not take into account changes over time. We found that the Dove Spring community, as a whole, ranges from -27.0 ‰ to -5.7 ‰, with a negative trend over time. Individual families show similar negative trends, suggesting herbivores indeed consumed almost exclusively C3 material but also increased their consumption of woody and herbaceous vegetation over time. Oxygen-18 results are in apparent disagreement with the carbon-13. $\delta^{18}O$ values increase over time, suggesting a local increase in temperature or a decrease in precipitation. Such climatic changes are usually associated with plant communities that are more water-efficient, such as grasses or other C4 vegetation. The negative correlation between isotopic systems may suggest that herbivores were not consuming local vegetation or that turnover in the plant community was insufficient to produce an enriched carbon-13 signal within the sequence. To address these hypotheses, we will conduct independent studies of vegetation and depositional environments. These studies will yield a primary signal of vegetation to compare with the herbivore record, and provide information on the amount of water available to the fossil communities inhabiting the Dove Spring Fm.

Biosynthetic gene clusters identified in cultured and *in situ* strains of *Microcystis aeruginosa* reveal high biosynthetic potential for diverse compound production

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Microcystis aeruginosa, a bloom-forming cyanobacterium, dominates cyanobacteria harmful algal blooms (cyanoHABs) in freshwater around the world, posing threats to water quality, wildlife, and stability of freshwater ecosystems. cyanoHABs are increasing in abundance, size, and duration as temperatures rise and runoff of nitrogen and phosphorus enter drinking water sources. *M. aeruginosa* is known to produce the nitrogen-rich hepatotoxin, microcystin, as well as a variety of other toxic secondary metabolites. Althoughsome secondary metabolites produced by *M. aeruginosa* have been identified, little is knownabout the chemistry, ecology, or impacts on human and ecosystem health of this wide array of metabolites. Here, we use genomic sequencing of our western Lake Erie culture collection and metagenomic sequencing of whole microbial communities from the 2014 western Lake Erie bloom to assess biosynthetic gene cluster composition and compound production in different *M. aeruginosa* strains. Our results indicate that *M. aeruginosa* strains isolated in the culture collection contain similar biosynthetic gene clusters to our metagenomic *M. aeruginosa*samples from the field. Compounds made by polyketide synthases I and III (PKSI and PKSIII), non-ribosomal peptide synthetases (NRPS), and hybrid NRPS-PKS pathways were most commonly identified in antiSMASH, a biosynthetic genome mining tool. antiSMASH also predicted several novel biosynthetic gene clusters from pathways putatively identified to encode for lanthipeptides and various cyclophanes. Lastly, there isevidence of structural variance in commonly found compounds in cyanoHABs such as aeruginosin, anabaenopeptin, and cyanopeptolin. These results require verification by biochemical methods such as liquid chromatography-mass spectrometry and molecular. networking,but the current results produced are vital in elucidating the biosynthetic potential of *M. aeruginosa in situ.* These data provide insights into novel compounds from cyanoHABs and may enhance bloom toxicity predictive models through investigation of how each compound is genetically encoded. This work also demonstrates the need for high resolution datasets on the metabolomics of *M. aeruginosa* strains, as well as further sampling and mass spectrometry analysison field samples of cyanoHABs to unlock novel chemical space and better understand what environmental proxies influence the dynamics of cyanoHAB chemistry.

The elusive theta aurora: how to reproduce unique auroral forms in simulations of the Earth's magnetic field

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The Earth's magnetic field interacts with solar wind plasma to form a highly dynamic and complex system called the magnetosphere that can extend over a million km away from the Earth's surface. However, within about 100,000 km of the surface, the Earth's internal dipole field confines particles in a magnetic bottle. The solar wind plasma compresses the dipole field on the dayside (facing towards the Sun) and stretches the dipole field into a cometary tail-like shape on the nightside (facing away from the Sun). The compressed dayside and stretched nightside configurations of the dipole field leak confined particles into the Earth's atmosphere, creating the aurora through collisions with atmospheric atoms and molecules. The auroral oval is a ring of auroral activity encircling both northern and southern polar regions that visually documents particle losses from the magnetosphere, thus revealing information about its structure. The polar caps inside each auroral oval are typically devoid of auroras. The theta aurora is a unique and poorly understood auroral form. During a theta aurora event, the auroral oval morphs from its ring-like shape into a structure that resembles the Greek letter theta: a thick bar of auroral activity stretches from one side of the auroral oval to the other, effectively splitting the polar cap in half. While the formation mechanisms for the theta aurora are still under debate, some theories suggest that certain solar wind plasma conditions can twist the Earth's magnetic field and that a highly deformed tail could provide a source for the theta aurora particles. We investigate the theta aurora by modeling the interactions between the solar wind plasma and the Earth's magnetosphere with the Space Weather Modeling Framework (SWMF). We drive the simulation with solar wind plasma data collected during the satellite-observed theta aurora event on May 15, 2005. We compare the simulation results of the auroral oval and polar cap to the satellite images of the theta aurora. We also analyze the Earth's stretched tail region dynamics during the theta aurora formation. We study the comparison between the model results and the observations to explore the physics involved in the theta aurora formation process.

Separation of spacecraft noise from geomagnetic field observations through density-based cluster analysis and compressive sensing

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Spacecraft equipped with magnetometers provide useful magnetic field data for a variety of applications such as monitoring the Earth's magnetic field. However, spacecraft electrical systems generate magnetic noise that interfere with geomagnetic field data captured by magnetometers. Traditional solutions to this problem utilize mechanical booms to extend magnetometers away from noise sources. This solution can increase design complexity, cost,and introduce boom deployment risk. If a spacecraft is equipped with multiple magnetometers, signal processing algorithms can be used to compare magnetometer measurements and remove stray magnetic noise signals. We propose the use of density-basedcluster analysis to identify spacecraft noise signals and compressive sensing to separate spacecraft noise from geomagnetic field data. This method assumes no prior knowledge of the number, location, or amplitude of noise signals, but assumes that they are independent and have minimal overlapping spectral properties. We demonstrate the validity of this algorithm by separating high latitude magnetic perturbations recorded by SWARM from noise signals in simulation and in a laboratory experiment using a mock CubeSat apparatus. In the case of more noise sources than magnetometers, this problem is an instance of Underdetermined Blind Source Separation (UBSS). This work presents a UBSS signal processing algorithm to remove spacecraft noise and eliminate the need for a mechanical boom.

Understanding biogenicity of microbial structures through 3-D imaging

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Microbialites, rocks formed by the interaction of microbes and sediments, are commonly used as records of past life and environments, but confirming biogenicity of putative microbialites can be challenging. 3-D imaging of microbialites and other microbial structures can be a valuable tool for confirmation and characterization of putative biogenic structures in the rock record. However, many methods (e.g., scanning electron microscopy, multiple thin sections) are destructive of the samples being studied. X-ray microcomputed tomography (μCT) scanning allows imaging of density structures and textures internal to samples and has previously been used both to confirm and refute claims of biogenicity in rock structures. With the development of a dataset of 3-D microbial structures in the rock record, μCT scanning could also be used to infer environmental mechanics and formation mechanisms of similar structures. I will be examining a diverse set of clastic microbialites from the Eocene (50 Ma) Green River Basin (GRB) in Wyoming to improve the utility of μCT scanning in identifying and studying microbial structures. I will sample the Rife Bed, which contains lacustrine microbialites and has previously been studied for its oil shales, and the Bridger Formation, which contains both lacustrine and fluvial microbialites. These units span the Paleocene-Eocene Thermal Maximum (PETM), a global high in CO_2 and temperature often studied as an analogue for anthropogenic climate change. Preliminary samples from these units include varied microbial textures, such as brain-like surfaces, layered ripples, and lithologic shifts. Further study of microbialites from these units with both μCT scanning and geochemical analysis such as ICP-MS will expand the record of the PETM, a valuable climatic proxy. Additionally, once a 3-D dataset of microbialites whose origins are well constrained (such as those in the GRB) has been developed, it can be used to aid in understanding the origins of other putative microbialites. 3-D imaging is a valuable tool for confirming biogenicity in microbial structures, but improving non-destructive methods for doing it and expanding the record of 3-D structures are essential for broadening its applicability.

Improved representation of the relationship between soil moisture and soil NO_x emissions

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Nitrogen oxides ($NO_x = NO + NO_2$) are an air pollutant responsible for a range of negative health impacts and ultimately are associated with increased mortality. Soils represent a significant source of NOx to the atmosphere, with an increasing relative contribution to overall United States (U.S.) NO_x emissions in recent years as fossil NO_x emissions have decreased. Among the environmental variables controlling soil NO_x emissions, soil moisture defines the amount of air within the soil pore space, which controls the magnitude of microbial activity that drive emissions. Generally, soil NO_x emissions are minimized at very wet or very dry soil conditions, and emissions are greatest at moderate soil moisture conditions. Within the Berkeley Dalhousie soil NO_x parameterization (BDSNP), a widely used soil NOx emissions model, a Poisson function scales emissions as a function of water-filled pore space (WFPS). This function produces peak soil NO_x emissions within a limited range of WFPS values (20 %–30 %). While soil NO_x emissions may peak within this WFPS range for certain regions, there is evidence for peak soil NO_x emissions occurring at WFPS outside this range. Here, we evaluate soil NO_x emissions over the contiguous U.S. by adapting the existing soil moisture function within the BDSNP to peak at different WFPS values than the existing function. We use three different gridded soil moisture products (ERA5, MERRA-2 and NLDAS-2 Mosaic)to drive the BDSNP with varying estimates of soil moisture. The revised BDSNP results indicate that the updated soil moisture function would broadly increase soil NO_x across much of the U.S. These results are strongly dependent on the gridded soil moisture product used to drive the model.

Holocene temperature and water budget records from lake carbonates in the Peruvian Andes (11°S)

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Carbonate $\delta^{18}O$ records ($\delta^{18}O_C$) from three adjacent lakes in the Peruvian Andes, Junín, Pumacocha, and Mehcocha, provide insights into Holocene precipitation and water budgets, but their interpretation is limited without independent controls on temperature and lake water evaporative loss. In this study, we use carbonate clumped (Δ_{47}) and triple oxygen ($\Delta'^{17}O$) isotope data to develop temperature and evaporation records from these lakes. Over the last 10,000 years, water temperatures derived from Δ47 were steady (Junín: 10 ± 2 °C, n = 9; Pumacocha: 11 ± 2 °C, n = 6) and match modern lake carbonate Δ_{47} temperatures in the region(13 ± 3 °C). Prior to 10,000 ybp, water temperatures at Junín were ~5 °C lower (6 ± 1 °C, n = 2), suggesting that Junín was cooler in the late Glacial than the Holocene. We also reconstruct lake water $\Delta'^{17}O$ and $\delta^{18}O$ values ($\Delta'17O_{rlw}$, $\delta^{18}O_{rlw}$) from carbonate Δ_{47}, $\Delta'^{17}O$, and $\delta^{18}O$ to test theassumptions that i) Pumacocha and Mehcocha δ18Orlw reflects unevaporated precipitation $\delta^{18}O$ and ii) Junín $\delta^{18}O_{rlw}$ is evaporated with respect to precipitation $\delta^{18}O$. As expected, $\Delta'^{17}O_{rlw}$ values are consistently lower at Junín than the other lakes and are lowest in the early to mid- Holocene (-11 ± 4 per meg; n = 6) before rising to 11 per meg at 1240 ybp. This indicates the evaporative fluxes from the lake during the Holocene were variable and generally larger than today. At Pumacocha and Mehcocha, $\Delta'^{17}O_{rlw}$ values average 29 (± 2 per meg; n = 3) and 24 per meg (± 3 per meg; n = 2), respectively for the last 3,500 years and are similar to $\Delta'^{17}O$ of modern precipitation (31 ± 5 per meg), affirming that Pumacocha and Mehcocha $\delta^{18}O_C$ values reflect precipitation $\delta^{18}O$ and are not influenced by evaporation. However, prior to 3,500 ybp, $\Delta'^{17}O_{rlw}$ values are 16 ± 6 per meg (n = 4) and 12 ± 6 per meg (n = 3), respectively, suggesting that either these lake waters were slightly evaporated or that precipitation $\Delta'^{17}O$ was lower than the present day. In sum, our results: 1) confirm that the Junín $\delta^{18}O_C$ record reflects both changesin Holocene precipitation $\delta^{18}O$ and evaporative fluxes from the lake, 2) suggest that Holocene lake water temperatures were similar to the present and were warmer than the late Glacial, 3) may challenge the assumption that evaporation did not influence Pumacocha and Mehcocha $\delta^{18}O_C$ records, and 4) highlight the insights that can be gained by adding Δ_{47} and $\Delta'^{17}O$ measurements to $\delta^{18}O_C$ records.

Analyzing the products of microbial iron cycling in an Archean ocean analog

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Banded Iron Formations (BIFs) are iron-rich marine sedimentary rock deposits thought to record the (bio)geochemistry of the ancient ocean. A low-Fe^{3+} silicate mineral, greenalite ((Fe^{2+}, Fe^{3+})$_{2\text{-}3}$$Si_2O_5(OH)_4$), has been identified as a primary iron mineral inclusion found in well-preserved BIFs. Thus, understanding how greenalite forms could offer insights into the activity of early life. We are testing the proposed hypothesis that photosynthetic bacteria in high silica environments utilize light energy to convert between ferrous iron (Fe^{2+}) and ferric iron (Fe^{3+}). This step is followed by Fe^{3+}-reducing bacteria then using organic carbon and ferric iron to fuel their metabolism, leading to the deposition of low-Fe^{3+} silicates. We conducted an iron cycling experiment in our lab with the iron-oxidizing bacterium *Rhodopseudomonas palustris* TIE-1 (TIE-1) and iron-reducing bacterium *Shewanella putrefaciens* CN32 (CN32) to investigate their iron products and determine if low-Fe^{3+} silicates such as greenalite are formed via their metabolisms. This two-step experiment simulated an ocean-like environment by first facilitating microbially mediated iron oxidation with TIE-1 in a synthetic Archean seawater analog (pH = 7.0, 2 mM Fe^{2+}, 1 mM Si) followed by microbial iron reduction of the precipitates by adding CN32 in an iron-free and silica-amended (pH = 7.0, 1 mM Si) seawater medium. Here I will discuss the results of the microbial iron oxidation step of the iron cycling experiment using TIE-1 in seawater medium (pH = 7.0, 1 mM Fe^{2+}, 1 mM Si). Modified collection techniques allowed for the further characterization of the iron-bearing precipitates via assessment of Fe redox state (using the ferrozine assay) and scanning electron microscopy (SEM). As we learn how low-Fe^{3+} silicates are formed, including whether iron cycling metabolisms can induce their formation, we can better understand if microbial life played a role in the formation of greenalite in the ancient ocean.

Understanding the formation of the manganese silicate braunite and its implications for the ancient manganese cycle

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Manganese, a multivalent transition metal, is often used as a paleo-redox proxy because of itsunique chemistry. The reduced form of this element (Mn(II)) is derived from igneous minerals and highly soluble since it can only be marginally concentrated by substituting for calcium in carbonates. As a result, modern manganese-enriched deposits primarily consist of oxidized Mn(III) and Mn(IV), which form insoluble (oxyhydr)oxides. Critically, this elementhas a particularly high redox potential, and is only oxidized and concentrated in sediments through interactions with oxygen or oxygen-related species in modern environments. Thus, concentrated deposits of sedimentary manganese minerals are considered tracers for oxygen. Large Paleoproterozoic and Neoproterozoic manganese deposits associated with rises in global oxygen contain substantial fractions of braunite ($Mn(II)Mn(III)_6SiO_{12}$). Although there is limited knowledge concerning braunite formation and its precursors, sedimentary textures suggest this mineral is a secondary (diagenetic) phase. Understanding the formation of braunite could reveal the depositional history and past biogeochemistry of manganese enriched sediments. We hypothesize that the requisite conditions for braunite mineralization are contingent on manganese oxidation and deposition, and that braunite is formed during diagenesis through interactions between an oxidized Mn precursor with silica-enriched sedimentary porewaters containing divalent manganese. We are testing this hypothesis by incubating different precursor Mn oxides in solutions containing varying concentrations of silicic acid and Mn(II) at diagenetic temperatures. Our initial results confirm that when a MnO(OH) precursor is incubated with Mn(II) and silicic acid at high temperatures, braunite is indeed formed. Our findings also stress the importance of Mn(II) in this reaction, as no braunite was identified when a MnO(OH) precursor was incubated in conditions with silica but lacking Mn(II). These simulated diagenesis experiments provide new insights on the cycling of manganese in ancient environments. The requirement of porewater Mn(II) suggests that reducing porewaters would be needed in paleoenvironments that form braunite.Moreover, the development of braunite from an oxidized precursor mineral verifies that manganese oxidation, and therefore oxic aqueous conditions, are imperative for the deposition of manganese-enriched sediments. Our results reinforce the understanding that thepaleo-depositional environment of these braunite-hosting formations most likely only existedafter the appearance of oxygen.

Galapagos coral P/Ca tracks local upwelling and shows intermittent links to biological productivity

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Ocean biological productivity is driven by nutrient supply to the photic zone, which primarily arrives through upwelling of deeper waters. However, records of available nutrient variability through time are scarce. Initial studies suggested that corals record seawater phosphate concentrations in their P/Ca ratios. Here we create a 22-year record of P/Ca from a *Porites lobata* coral form Wolf Island in the Galapagos, located in the eastern equatorial Pacific. We use this record to examine phosphate variability and whether it tracks other coralproxies, satellite-based sea surface temperature (SST), and/or surface ocean chlorophyll through time. We find that P/Ca correlates strongly with coral-based SST proxies ($\delta^{18}O$ and Sr/Ca) and satellite-based SST but does not always correlate with satellite-derived chlorophyll (biological production). However, some years show strong positive links between nutrients (P/Ca) and biological production (chlorophyll). This indicates that, though phosphate is an important nutrient sourced from upwelling, other factors in the Galapagos influence productivity. Limiting nutrients such as iron and nitrate also modulate biological productivity and should be considered in eastern equatorial studies of nutrients.

Photochemical oxidation of methane in arctic surface waters

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The Arctic is warming 2–4 times as fast as the rest of the Earth due to human-caused climate change. Thawing permafrost results in release of methane from arctic lakes to the atmosphere, where it is a greenhouse gas that further amplifies climate change. However, some of the methane made in arctic lakes is oxidized to carbon dioxide before it is emitted to the atmosphere. Carbon dioxide is ~25 times less potent of a greenhouse gas compared to methane. Thus, understanding the controls on the oxidation of methane to carbon dioxide are critical for predicting how release of methane from thawing permafrost soils will amplify climate change on Earth. Current understanding is that oxidation of methane in lakes is a biological process, carried out by microorganisms in the lake. However, photochemical (sunlight-driven) processes produce hydroxyl radicals in high concentrations in arctic lakes. Hydroxyl radical is a highly reactive oxidant capable of oxidizing methane to carbon dioxide.No study has tested the potential importance of methane oxidation by hydroxyl radical in anynatural waters, including arctic surface waters. To address this knowledge gap, we quantifieddissolved methane loss in filtered surface waters upon exposure to simulated sunlight (and thus hydroxyl radical) relative to dark controls. Some waters showed up to 2 ± 1.75 uM loss of methane compared to dark controls, while other waters showed no detectable loss of methane upon exposure to light. In waters with detectable photochemical methane oxidation,the rate was 10–25% of rates measured in arctic lakes. This preliminary, conservative estimate of photochemical methane oxidation suggests that it may account for a substantial fraction of methane oxidation currently assumed to be biological in arctic lakes.

Carbonate paragenesis in the Afar rift system, Ethiopia: insights from clumped isotope thermometry and petrography

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Reconstructing temperature and seasonality of the last interglacial from analysis of stable oxygen isotopes in Bermuda bivalves

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Reconstructing climate during periods of past global warming can improve predictions for future climate change. During the Last Interglacial period, the Earth experienced a climate 1–2°C warmer and a global sea level 6–9 m higher than today. Fossilized shells of *Lucina pennsylvanica* were collected from marine carbonate deposits of Bermuda that formed duringthe Last Interglacial period and are currently exposed above the waterline in Bermuda. We measured multiple shells from each layer at high resolution to determine the $\delta^{18}O$ isotope values throughout these shells' lifetimes. Shells $\delta^{18}O$ value were combined with the current $\delta^{18}O$ value of ocean water near Bermuda, 1.3 ‰, to calculate the ocean temperatures from when these shells were alive over 116,000 years ago. The high-resolution $\delta^{18}O$ analysis revealed a pattern indicating a seasonal temperature range similar to today. We compared shells between layers to determine if there was a change in seasonality through time. Prior clumped isotope research of Bermuda suggested this location was colder despite an overall warmer global climate. In the future we will be able to use clumped isotopes testing to further our knowledge and strengthen our research into this remarkable and historical climate.

Morphology and anatomy of a Bennettitalean ‘fruit’, *Paleoaster*, from the Late Cretaceous of North America

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Paleoaster is an enigmatic taxon within the extinct group of Mesozoic plants called Bennettitales. Fossils have been found in Late Cretaceous strata from North America, in bothmarine and transitional depositional environments. *Paleoaster* was previously described as a fruit of the poppy family (Papaveraceae). Originally it was known only from impressions andcasts, but we have permineralized specimens now available with internal structure. By studying ground sections, acetate peels and CT scanned data we provide a morphological andanatomical basis to understand the whole ovulate reproductive structure of *Paleoaster*. We argue it should be expelled from the angiosperms due to its bennettitalean ovules and providenew data on the morphology of whole ovulate structure (‘fruit’). These morphological and anatomical data can be combined with chronologic, stratigraphical and phylogenetic data for a better understanding of the diversity and evolution of the reproductive structures within Bennettitales.

Influence of shear-wave velocity heterogeneity on SH wave reverberation imaging of the mantle transition zone

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In addition to SS precursors, the travel times of long-period (T > 10 s), teleseismic topside shear-wave reflections may be useful to constrain the depths of discontinuities in the upper mantle. We focus our attention on waveforms from the US Array and the topside reflections Sv410 and Sv660 at the 410-km and 660-km, respectively. Using waveform data from the US Array and spectral-element method synthetics for 3-D seismic models, we illustrate that a common-reflection point (CRP) modeling of layering in the upper mantle must be based on 3-D reference structures and accurate calculations of reverberation travel times. Our CRP mapping of recorded waveforms places the 410-km and 660-km phase boundaries about 15 km deeper beneath the western US than beneath the central-eastern US if it is based on the 1D PREM model. The apparent east-to-west deepening of the MTZ disappears in the CRP image if we account for shear-wave velocity variations in the mantle. We also find that ray theory overpredicts the travel time delays of the reverberations if 3-D velocity variations in the mantle are prescribed by global models S40RTS, SEMUCB-WM1, and TX2015. Undulations of the 410-km and 660-km are underestimated in the analysis when their wavelengths are smaller than the Fresnel zones of the wave reverberations in the MTZ.

Near-surface shallow velocity model using Distributed Acoustic Sensing and ambient seismic noise in an urban area: Granada, Spain

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Applications of vertebrate fossils from Sage Creek Basin, MT to potential insights about Cenozoic Basin and Range extension

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Effects of anthropogenic nutrient runoff on grazing pressure and fish-mediated biogeochemical hotspots in seagrass beds through space and time

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Phenotypic plasticity of cyanobacterium *Microcystis* in Lake Erie via gene quantification of different CO2-Concentrating Mechanisms (CCMs)

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Microcystis is one of the most pervasive toxic cyanobacteria species whose robust phenotypic plasticity, or ability of a species with the same genotype to display different phenotypes at various experimental conditions, has puzzled researchers attempting to explainspecific strain-level drivers of bloom development. Previous research that has extensively looked at the presence of toxin producing (*mcy)* genes in *Microcystis* has yet to provide cohesive evidence for specific adaptations to changing environmental conditions. In contrast,recent studies focused on specialized cyanobacterial CO_2-uptake genes has begun to shed light on potential strain-level dominance. Specialized CO_2-Concentrating Mechanisms (CCMs) found in freshwater cHABs have identified three different cyanobacterial genotypesthat have different environmental responses (ecotypes). These ecotypes differ in their physiological response and photosynthetic efficiency at different pH levels/carbon availability (Ci). Specifically, they differ in the presence, absence, or combination of two bicarbonate (HCO^{3-}) associated genes, *sbtA* and *bicA*, each with contrasting affinity and efficiency in uptake. The shuffling of these ecotypes over bloom succession allows for a *Microcystis* community to take advantage of a broad range of Ci. Further, this multi-specialistplasticity is also expected to increase with climate change. In Lake Erie (LE) where *Microcystis* dominates in the summer, there is a lack of evidence on CCM ecotypes. This study takes advantage of UofM's Geomicrobiology culture collection (UMGCC) containing 29 representative strains of *Microcystis* isolated from LE from 2017–2020 along with metagenomic field samples from the LE 2014 bloom to analyze the growth and photosynthetic ability of different CCM ecotypes. Gene quantification results of the presence/absence of CCM genes of all UMGCC contained all three ecotypes. Of these 29, five strains were selected for a 21-day culture experimental conditions (23 °C, 400 µ/mol light,12:12 light: dark). Daily cell concentration and pH measurements were taken to analyze physiological and photosynthetic efficiencies over the course of the experiment. Results of this experiment are currently in the process of being paired with genomic analysis of whole community samples from bloom development in 2014 to pair succession of these ecotypes with environmental metadata characteristics that can be used to analyze bloom succession. The results of this study will provide important insight on different WLE CCM ecotypes andhopefully work to provide evidence of how certain CCM genes results in ecotypes that make*Microcystis* one of the most ubiquitous and notorious cyanobacterial competitors in freshwater ecosystems worldwide.

Modeling and quantifying the dry deposition of phosphorus in the Great Lakes region

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Anthropogenic phosphorus (P) is a main driver of harmful algal blooms such as those that occur in Lake Erie. While agricultural and urban runoff is a dominant source of phosphorus, industrial processes, dust, and biomass burning can also emit phosphorus to the atmosphere. However, the contribution from atmospheric processes such as wet and dry deposition are unknown. We seek to understand the ratio of wet-to-dry deposition by calculating the amountof dry P deposition over the Great Lakes. Using ground-based aerosol measurements from the IMPROVE observation network and meteorological data from ECMWF reanalysis, we calculate the phosphorus deposition using a resistance-based dry deposition model at 14 locations in the Midwestern United States grouped within three regions: the Boundary Waters Region, the CentralGreat Plains Region, and the Ohio River Valley Region. We estimate the monthly average dry P deposition to the Great Lakes and discuss the relative contribution of this atmospheric source.

Solar cycle, seasonal, and spatial variability of Mars' upper atmosphere: MAVEN measurements and numerical model simulations

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Ocean temperatures along the United States east coast during the last interglacial period as determined by $\delta^{18}O$ of the bivalve *Mercenaria*

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The last interglacial period, which was around 150,000 years ago, was the most recent time in Earth's history that the climate was relatively similar to what it is today. It is important to research the climate before, during, and after the last Interglacial Period so that we can compare the current climate trends to past trends and potentially predict the future of the climate. In my research on the last interglacial period, I looked at *Mercenaria* shells collected from field sites in Massachusetts, Virginia, and South Carolina. I used a hand drill to drill tiny holes down the center axis of each shell, and I performed stable isotope analysis on each of the samples gathered from the drilling. The stable isotope analysis gave me the $\delta^{18}O$ and $\delta^{13}C$ valuesover the lifetime of the shells, which I will use to determine the temperature of the water during the growth of the shell. This temperature data is especially important because the temperature during that time period has primarily been studied in the northeast Atlantic, andthis will fill in the data gap on the eastern United States coast, especially the southeast, that other research has left.

Reading the leaves: interpreting how monocot leaf venation was influenced by evolutionary environmental, and physiological constraints

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Leaf veins are instrumental for plants to flourish in environments by driving water transport and helping to reduce desiccation. Vein density, or vein length per area (VLA), is an important part of leaf venation as it is directly correlated to photosynthetic rate, hydraulic conductance and overall gas exchange. Although much is known about VLA patterns in otherwoody angiosperms, there is uncertainty about how monocot VLA is influenced by environmental conditions, plant physiology, and phylogenetic history. Monocot flowering plants share many aspects with eudicots but they have their own unique physiologies and traits. The aim of this study was to explore how phylogenetic, physiological, and ecological constraints influenced VLA arrangement in monocots and to test for the eudicot global leaf venation and size scaling relationship in monocots. The dataset in this study used 814 monocot species, consisting of cleared leaves and newly collected non-cleared herbaria leaves. Our data suggests that closely related monocot species do not share similar values of VLA, both along the clade and ordinal levels. Ecological and plant physiological constraints appeared to have greater influences on the formation of VLA. Lastly, our results show that all types of monocot VLA are independent of leaf size, which directly opposes the global leafvein scaling in eudicots.

Calibrating the clumped isotope paleothermometer (Δ_{47}) for marine gastropods

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Clumped isotopes—heavy isotopes bonded to other heavy isotopes—are used in paleoclimate research to reconstruct temperature and climate variability from the past, which can inform us about climate change in the future. Specifically, the 'clumped isotope paleothermometer' is a method that defines a relationship between clumped isotope composition (Δ47) and growth temperature of biogenic carbonates (e.g., bivalves, brachiopods, foraminifera). Calibration studies suggest that this relationship is standard across most taxa investigated. However, previous studies have largely overlooked marine gastropods (e.g., snails, whelks) in their sample selections. Marine gastropods exist across a wide range of both time (i.e., many fossil families extending to the late Cambrian) and space (i.e., habitat diversity), making their potential as a paleoclimate archive high. They also grow faster relative to many other biogenic carbonates, making it possible to reconstruct seasonal temperature variability through sclerochronology more easily. In this study, we aim to: (1) calibrate the clumped isotope method for more marine gastropod species, and (2) determine whether certain gastropods exhibit 'vital effects' (i.e., precipitate their shells of out equilibrium with surrounding ocean water) that may alter Δ_{47} values and thus bias reconstructed growth temperatures. This project will identify marine gastropod species that are viable for paleotemperature reconstruction and allow for greater temporal and spatial resolution in the paleoclimate record. And in the larger framework of paleoclimate research, this study will eventually help us gain insights on climaticprocesses such as ocean circulation, sea level rise, and sea ice melt.

Examining the influence of different environmental conditions on the growth and ecophysiology of *Microcystis* strains isolated from Lake Erie

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Cyanobacterial harmful algae blooms (cHABs) occur when there are high light levels, warm temperatures, and significant influxes of limiting nutrients; all of which are predicted to increase, as a result of anthropogenic impacts and climate change. *Microcystis* (M) often dominates these blooms and is capable of producing the hepatotoxin microcystin (MC), which is problematic because people often rely on freshwater lakes impacted by eutrophication, such as Lake Erie (LE), for drinking water. Since cHABs occur annually in LE (typically from June-October), there are concerns that climate change will lengthen/intensify bloom seasons that already have negative public health and economic ramifications. In order to better predict, forecast, and characterize the occurrence of LE cHABs, a strong understanding of bloom dynamics is vital. In previous research, evidence ofstrain-level adaptations that drive bloom dynamics has most extensively focused on M's genetic ability to produce MC if complete *mcy* gene operons are present. However, there is a lack of a cohesive consensus between different studies occurring at different locations, whichpresents a knowledge gap in the dynamics and ecophysiology of cHABs. To address the knowledge gap, this study consists of subjecting five different M strains from the University of Michigan Geomicrobiology Laboratory's culture collection (2 strains from 2019, 1 from 2018, and 2 from 2017 that produce different concentrations of MC) to different light intensities (100 umol, 200 umol, 300 umol, 400 umol, and 600 umol), temperature levels (23 °C,21 °C, and 27 °C), and nitrogen sources (NO^{3-}, NH^{4+}, and urea) in a series of growth experiments. Only several of the light intensity experiments have been completed, but we plan to experiment with all combinations of our predetermined environmental conditions. Each experiment has 14 time points taken during consecutive weekdays. Corresponding dailymeasurements of cell concentrations will be used to calculate growth rates via a Gompertz growth model. The strain-specific growth rate resulting from different conditions will be compared to analyze any significant trends that may enhance our understanding of the dynamics and ecophysiology of M. Our findings may also be informative for predicting how M will respond to climate change progression. This study will later be combined with a coupled hydrodynamic-ecological model to advance cHABs modeling, predictions, and forecasting, as well as aiding in the development of science-driven preventative policies.

Sunlight exposure controls the lability of dissolved organic matter to photomineralization in arctic surface waters

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The oxidation of dissolved organic matter (DOM) to carbon dioxide by sunlight (photomineralization) accounts for approximately 50 % of the carbon dioxide produced in thewater column of arctic surface waters. Despite the importance of photomineralization within the arctic carbon cycle, little is known about how the lability of DOM to photomineralization changes over time as a result of sunlight exposure in surface waters. The lability of DOM to photomineralization is expected to decrease over the course of sunlight exposure, as the most photolabile components of DOM become depleted. To test this hypothesis, we exposed arcticsurface waters to increasing amounts of ultraviolet (UV) and visible light. After each light exposure, the lability of DOM to photomineralization was quantified as the amount of carbondioxide produced per photon absorbed by the chromophoric fraction of DOM. An order of magnitude increase in the amount of light exposure produced a 45 to 90 % decrease in the lability of DOM to photomineralization, consistent with the rapid depletion of a highly photolabile fraction of DOM during light exposure. This effect of light exposure dominated the effects of DOM composition or water chemistry on the lability of DOM to photomineralization. Additionally, in high-iron surface waters, the lability of DOM to photomineralization decreased more rapidly during exposure to visible light than during exposure to UV light. Because over 90 % of the photon flux from natural sunlight occurs at visible wavelengths, this result implies that water column rates of photomineralization in high-iron surface waters decrease substantially with increasing light exposure. Overall, our results demonstrate that conclusions about the importance of photomineralization for carbon dioxide production in arctic surface waters are strongly dependent on the history of light exposure of DOM in these waters.

Analysis of human induced earthquakes in Oklahoma

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Human induced earthquakes are increasing in frequency throughout the continental U.S., including many regions not previously prone to earthquakes. To understand the amount andlocation of anthropogenic earthquakes, I compare databases tracking both natural and anthropogenic earthquakes to see any change in the historical pattern in Oklahoma. I conclude that the number of earthquakes in Oklahoma has increased significantly within thepast two decades due to anthropogenic activity and that this rise is mostly due to hydraulic fracking. While anthropogenic earthquakes are escalating throughout the continental U.S., Oklahoma has seen a large growth in both the magnitude and number of earthquakes. Understanding this change is important to help determine the risk and future mitigation. Whether the rise in the number of earthquakes in Oklahoma is due to the diligent tracking ofearthquakes from the Oklahoma Geological Survey or actual increase in frequency, remains unknown.

A new lungfish (Sarcopterygii: Dipnoi) from the Late Devonian (Frasnian) Fram Formation, Nunavut, Canada

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Recent expeditions to the NV2k17 locality, Late Devonian (Frasnian) Fram Formation of Ellesmere Island, Nunavut, Canada have uncovered an ecosystem consisting of placoderms, porolepiforms, tetrapodomorphs, and dipnoans. This assemblage bears a striking similarity tothe Upper Devonian (Frasnian) Escuminac Formation of Miguasha, Quebec, Canada with one major difference—the most abundant lungfish in the Escuminac is *Scaumenacia curta,* whereas it appears to be completely absent from the Fram Formation. In its place is a new species described here. We diagnose this new lungfish using the E bones scalloped laterally by the 'M' and 'L2' bones, elongated heptagonal 'B' bone with a small anterior projection, expansive pustular and vermiform ornamentation that extends to the anterior portion of C bone and becomes more pronounced laterally, and the much larger body length of approximately one meter. Additional material is also used to enhance the description, including various skull roofs, incomplete lower jaw elements, opercula, shoulder girdle, and an articulated postcranial skeleton, among an assortment of other smaller bones. This articulated specimen allows for further comparison with material previously available for *Scaumenacia*, discussion of its place in the general ecosystem of the Fram Formation, and adds a new lens with which to examine the diversity of Late Devonian lungfishes.

Iron oxide apatite deposits, an untapped vanadium resource

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Vanadium is a critical element as it is necessary in steel alloys and in V redox batteries, both of which are essential for the development of a low-carbon energy infrastructure. Vanadium is traditionally a by-product of the extraction of Fe and Ti in magmatic deposits and of U in sediment-hosted U-V deposits. Its current production is limited, and its demand is forecasted to increase significantly, so new sources of this element will be needed in order to achieve the required supply. Iron Oxide-Apatite (IOA) deposits are dominated by magnetite, an iron oxide mineral. They are major sources of Fe and recent studies have shown that they can contain substantial V hosted in magnetite as well. This project explores the favorable physicochemical conditions for the formation of V-rich magnetite in these deposits. Magnetite in IOA deposits is thought to result from magmatic-hydrothermal processes but the exact conditions of the hydrothermal fluid from which it precipitates are still unclear. We present the thermodynamic modelling of aqueous speciation of a hydrothermal fluid that exsolves from a melt of intermediate composition. Our model evaluates the behavior of V-species in the fluid as a function of temperature, pressure, pH, and fO_2. Our results indicate that V incorporation in magnetite is favorable at high temperatures and acid pH conditions. We also modelled the efficiency of removal of V by a magmatic volatile phase. Our results show that a standard magma chamber (50 km^3) with an average initial V content can supply enough V to a hydrothermal fluid to concentrate more than 30,000 tons of V in an ore body. Our results indicate that purely hydrothermal magnetite can host considerable amounts of V in its structure and that the parental melt for the hydrothermal fluid needs to be of intermediate composition. These results have implications within the tectonic setting that is suitable for the formation of IOA deposits, which will allow for improved exploration campaigns to more efficiently find this type of deposit in order to increase the resources of V needed for the transition to environmentally-friendly energy supply and storage.

1-, 2-, and 3-D increments in a mammoth tusk: growth rates and probabilistic life history reconstruction

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Mammoth tusks often exhibit variable density corresponding with periodically variable growth through the life of the animal. Among the most pronounced of these signatures are those that correspond with annual growth. In female mammoths, there is a multiannual pattern of variation in size of increments, and this may correspond to a multiannual pregnancy-birth-nursing-weaning reproductive cycle also observed in modern elephants. Interpreting this repeating, multiannual pattern as reproductive in nature allows us to infer thenumber of calves each female produced through her life and the interval of time between calves—two important aspects of life history used in population and extinction risk modeling. However, there is a limited set of other possible interpretations of such patterns, which include both environmental hardships and interrupted reproductive cycles (calves that die before weaning). Furthermore, the patterns in increment measures differ depending on thetype of measurement, due to the complex geometry of tusk growth and how shape of tusks changes with growth through life. Here I evaluate 1-, 2-, and 3-dimensional increment measures in a woolly mammoth tusk first to describe how tusk shape changes through life. Then, I apply a probabilistic approach to evaluating the potential life history interpretations considering all possible interpretations. This approach provides an objective framework to measure number of calves and calving interval, to constrain the full range of possible data forpopulation and extinction risk models from mammoths. The faithful representation of calvinginterval in these models is critical for understanding how populations declined as mammoths went extinct, information that in turn can help us craft better conservation measures for endangered elephant populations to prevent extinction in the future.

Understanding Late Cretaceous climate through isotope-based ocean temperature reconstructions from Owl Creek, MS

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The Maastrichtian age was the final age of the Cretaceous period, ending with the meteor collision that caused the K-Pg extinction. During this period in time, there was ahigher concentration of CO_2 in the atmosphere. The goal of this study is to estimate the ocean temperature near modern day Owl Creek, MS right before the mass extinction event. The study site is located in the Gulf Coastal Plains in Mississippi. Bivalve fossils were collected from the formation and were then examined for their preservation by imaging samples in a Scanning Electron Microscope (SEM) to determine if the samples were contaminated by growth of secondary calcite material. Good samples were then powdered and submitted for clumped isotope analysis. Each sample powder was replicated at least threetimes. We found an average temperature of ~24 ° Celsius. The results of this project will allow us to help predict the future of the planet. The increasing concentration of CO_2 in our atmosphere could become similar to the conditions at the end of the Cretaceous. With this new data, we can estimate how climate in the northern mid-latitudes may change with the projected increases in CO_2 concentration.

Cooling time scales of lunar 74220 orange glass beads from Na and Cu profiles

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Formed in fire-fountain eruptions, the lunar 74220 orange glass beads are known to have undergone extensive outgassing. The outgassing effect leads to lower concentrations of volatiles in the orange glass beads than in olivine-hosted melt inclusions (OH-MIs) in the same sample, and resulting in decreasing volatile contents in the glass beads towards the surface. We previously reported U-shaped Na concentration profiles across 74220 orange beads measured by EMPA and SIMS with Na enrichment near the bead surface, and proposed that they were formed by first outgassing and then in-gassing of Na. Here, we show that Cu concentration profiles in the same orange beads are also U-shaped as mapped by LA-ICP-MS. Similar U-profiles in both moderately volatile Na and Cu confirm these beads have experienced both first out-gassing and later in-gassing when they were flying through the volcanic gas plume and falling back to the lunar surface. The in-gassing might be attributed to a transient and localized atmosphere. To understand the whole process that forms the U-shaped profiles of Na and Cu, a quantitative diffusion model is developed. The model assumes an asymptotic cooling history for spherical glass beads with a homogeneous initial composition and surface equilibrium with the ambient atmosphere. The model leads to out-gassing at high temperature and subsequent in-gassing as beads cool down. By fitting the measured Na and Cu profiles, cooling time scales of individual orange glass beads are estimated. It is found that cooling time scales of the orange glass beads have a positive relationship to bead diameter, consistent with size-dependent heat transfer coefficient. Cooling time scales modeled from Cu profiles are about half of those from modeling Na profiles. The difference might reflect errors in the input data (such as diffusivity as a function of temperature) and potential uncertainties in the model.

Does the central Pacific decline in ENSO variability 4000 years BP extend to the eastern Pacific?

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The El Niño Southern Oscillation (ENSO) is the dominant pattern of climatic variability in the tropical Pacific, and the largest modern interannual pattern of climate variability in the world. Transitions between El Niño and La Niña phases of ENSO are associated with dramatic shifts in precipitation and temperature regimes in the tropical Pacific, and these climate extremes create hazardous conditions within the Pacific and beyond. Understanding future patterns in ENSO variability is therefore critical to our preparation for anthropogenic climate change. However, the spatial and temporal variability of ENSO in the coming century is poorly constrained by climate models. Paleoclimatic proxy data is necessary to understand the full range of ENSO's natural variability and identify potential forcings associated with increased or decreased ENSO variability. Previous studies analyzing the geochemical composition of *Porites lobata* corals in the central tropical Pacific (CP) have identified a period of low ENSO variability spanning 3,000-5,000 years before present (BP).We are studying the isotopic and trace element composition of a 4,141-year-old coral skeleton from San Cristóbal Island in the eastern tropical Pacific (EP). We are isolating the ENSO-driven temperature signal from this geochemical data to assess whether ENSO variability in the EP decreases in parallel with that in the CP, or whether it behaves independently. Preliminary data suggests that ENSO is behaving differently across these regions during this interval, with the San Cristóbal temperature signal 4,000 years BP showing variability consistent with average preindustrial ENSO (rather than the dampened cycle seen in the CP). Understanding the spatial pattern of this unique shift in the mid- Holocene ENSO will allow us to evaluate modeled results of this interval and improve predictions of future ENSO-driven change.

Machine-learning-based location of volcano-seismic sources

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One important task in volcano monitoring and research is the determination of the location of underground volcanic processes which are recorded by seismic sensors. Among different classes of volcano-seismic events, volcano-tectonic (VT) earthquakes are routinely located using accurate seismological methods which involve careful human inspection. Due to their different seismic characteristics, other types of events are not subject to this methodology, but share other common features with VT events, such as the amplitude attenuation with distance. In this project we exploited the wealth of data available in seismic catalogs to train machine learning models for automatic location of different types of volcano-seismic sources. We follow two lines of investigation, applying different methods to the same dataset from the Kilauea volcano caldera collapse in 2018. In our 1st component, we implemented a convolutional neural network (CNN) that ingests the raw waveforms records to output a sourcelocation. In our 2nd component, we extract amplitude features and train "classical" machine learning regression models. We analyze the dataset from the perspective of the seismic attenuation model to demonstrate that the features are useful in representing the attenuation of seismic waves. When testing, the CNN outperforms the models of our second component. Nevertheless, the latter approach can be generalized to continuous tremor signals which are much longer than VT events. In fact, our application of these models to tremor signal is consistent with results obtained by means of other geophysical non-ML methods reported inthe literature.

Resolving the *Tomistoma-Gavialis* Relationship Controversy

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The Indian gharial (*Gavialis gangeticus*) and the Indonesian false gharial (*Tomistoma schlegelii*) are members within Crocodylia, a clade of semi-aquatic predatory reptiles that first appeared in the Lower Cretaceous and today is represented by three families, Alligatoriidae, Crocodylidae, and Gavialidae. Despite the well-supported relationship of the three families by fossil and molecular evidence, the taxonomic placement of *Tomistoma* is still considered contentious in systematics. While molecular datasets support *Tomistoma* as more closely related to *Gavialis* than other extant crocodylians with a diverging time estimate in the Miocene, morphological datasets resolve *Tomistoma* as more closely related Crocodylidae and Alligatoridae, and *Gavialis* diverging from these clades during the Upper Cretaceous. Here, we present a preliminary morphological dataset based on published data matrices, revisions, modifications, and firsthand observations of a large sample of fossil andextant crocodylians (122 taxa and 494 morphological characters). The dataset was analyzed using a tip-dating technique and the fossilized birth-death model under a Bayesian framework to test 1) the *Gavialis*-*Tomistoma* relationship and 2) the divergence time of bothclades. The results of the Bayesian analysis recovered *Tomistoma* and its closest fossil relatives as a monophyletic group (subfamily Tomistominae) most closely related to *Gavialis* (Gavialidae) than to Crocodylidae and Alligatoriidae, however with a divergence time in the Cretaceous (77–102 Ma). These results show that some morphological charactersconsidered homosplastic within Tomistominae may be interpreted as homologous. The reason why historically morphological datasets resolved *Tomistoma* outside Gavialidae maybe probably because of sampling bias due to lack of fossil material and how characters werechosen for certain analyses. This study shows the importance of including a large number oftaxa (fossil and extinct) and a wide range of morphological characters to understand the complex evolutionary history of clades that span from the Mesozoic to recent times.

The Resilience Project: water quality in southern Michigan

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[Not included in DOI at presenting author's request]

Ozone depletion event timescales and influence of NO_x on Background Ozone Levels in the Arctic

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Tropospheric ozone is an air pollutant and greenhouse gas and is detrimental to human health and the environment. Atmospheric ozone depletion events (ODEs) occur frequently in the troposphere in the polar regions during springtime. During these events, ozone drops rapidly from background levels, sometimes to near zero. Understanding of the temporal and spatial scales of these ODEs remains limited because of few observations. Arctic ozone and meteorology measurement data were analyzed with the goal of assessing the spatial variabilityof ODEs occurring at Utqiaġvik and Oliktok Point, AK, located hundreds of kilometers apart. We hypothesize that reaction of ozone with nitrogen oxides (NO_x) emitted from the North Slope of Alaska oil fields contributes to lower background ozone at Oliktok Point. To isolate the impact of NO_x emissions on Oliktok Point, we examined January ozone concentrations to estimate background ozone based on the assumption that springtime ozone depletion photochemistry was not occurring. Utqiaġvik averages were calculated using ozone data coming from the direction of the Beaufort Sea to minimize the impact of local pollution, while Oliktok Point averages were calculated using data from all wind directions. With this understanding of the NOx influence, we examined the co-occurrence of ODEs at both Utqiaġvik and Oliktok Point, AK.

Utilizing electron heat flux to improve IMF polarity specification for validation of the WSA model

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The corona and solar wind predictions of the Wang-Sheeley-Arge (WSA) model are validated by in-situ solar wind observations. The original method for validating the predictedinterplanetary magnetic field (IMF) polarity only considered the observed Bx component of the magnetic field based on the simple Parker Spiral model. This approach fails about 25% ofthe time when the magnetic field does not fit this simple paradigm due to magnetic switchbacks, transients, co-rotating interaction regions, etc. Previous work has shown that theelectron heat flux is one method of determining the in-situ IMF polarity of the solar wind. We created a rigorous methodology to reliably determine the IMF polarity using observed electron heat flux from the ACE spacecraft. From this, a new set of criteria, along with uncertainty estimates, was created using the B_x and B_y components of the magnetic field to specify the IMF polarity for validation of the WSA predictions, since the electron heat flux data is not available for real-time forecasting. This set of criteria was implemented in the dataused to validate the WSA model and the results are presented here.

Was there plate tectonics in the Archean eon? A case study of metamorphic rocks from the Minnesota River Valley

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If and how plate tectonics operated in the Archean eon remains a controversial topic. The Minnesota River Valley (MRV) gneiss terrane is comprised of multiple tectonic “blocks” with diverse igneous and metamorphic rocks dating back to over 3.5 Ga. Therefore, its geologic history offers a scope to understand the tectonic processes that drove the evolution of early continents. This study presents EPMA mineral chemistry and XRF whole-rock composition data on gneiss samples collected from the amphibolite-facies Morton and granulite-facies Montevideo blocks of MRV. We use thermobarometry to estimate the pressures and temperatures under which they were metamorphosed. We compare the metamorphic conditions of these two neighboring blocks to test whether they formed under ashared or separate geothermal gradients, which in turn implies whether their formation is consistent with the operation of plate tectonics in the Archean eon.

Assessing the potential of bivalve *Lucina pennsylvanica* as a recorder of past mean annual temperature and seasonality

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Paleotemperature/paleoseasonality reconstruction relies on physical, chemical, and biological materials preserved within the geologic record. The use of a proxy to reconstruct past climate requiresan understanding on how that proxy is related to climate. Well preserved bivalve shells of *Lucina pennsylvanica* exist in both modern and fossil record, dating back to the Pleistocene. Here, we calibrate isotope techniques including $\delta^{18}O$-, Δ_{47}-, and high resolution (H.R.) Δ_{47}-based thermometry in modern *L. pennsylvanica* to verify their ability to record mean annual temperatures and seasonalityto establish the relationship between climate processes and this biological proxy. Overall, we observe neither mean temperature nor seasonal bias in modern *L. pennsylvanica*. Summer-winter averaged $\delta^{18}O_{carb}$-based temperature reconstruction shows the closest agreement with observed seasonality while Δ_{47}-based mean temperature reconstruction produces the closest alignment with modern mean annual temperatures. We applied two strategies of combining data (data smoothing and optimization) to the H.R. Δ_{47}-based temperature reconstruction. Ofthese two approaches, data optimization achieves better precision and can resolve smaller seasonal temperature differences. We recommend pairing H.R. Δ_{47}-thermometry (data optimization) with either the $\delta^{18}O_{carb}$-based or Δ_{47}-based temperature reconstruction when applied towards paleo records to achieve the most reliable seasonal reconstruction.

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