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The Development of Neogene Planktic Foraminiferal Latitudinal Diversity Gradients and Species Richness in the Tasman Sea

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The latitudinal diversity gradient (LDG) of species richness is an ecological phenomenon seen in many animal and plant species. This pattern describes the highest diversity of organisms in the tropics, and lowest in the polar latitudes. Planktic foraminifera have been around since the Jurassic and their rapid reproduction and exceptional fossil record enable their use as proxies for evolutionary patterns. Modern and extinct planktic foraminifera are found in marine environments across all latitudes in the upper water column. Their distributions in ocean sediments allows paleontologists to examine the diversity gradients of marine plankton.

Studies of modern planktic foraminifera species richness across latitudes indicates the LDG may not hold for this group of protists. Previous studies indicate species richness peaks in mid-latitude regions of the North Atlantic during the Pliocene, with the highest species richness in mid-latitude regions. However, it is unknown if species richness was always highest in the mid latitudes, or if it developed in conjunction with global cooling and reorganization of wind-driven currents. One explanation for this may be the presence of strong western boundary currents that transport subtropical waters to the midlatitudes. These currents occur on the western side of large subtropical gyres, off the east coast of large land masses, and are areas of increased upwelling. Here, we examine the effect of the formation of the Tasman Front, a western boundary current in the Tasman Sea, on late Neogene (14-0 Ma) planktic foraminiferal species richness. The Tasman Front meanders between 31˚ and 37˚ S, beginning on the edge of the East Australian Current. Specifically, we determine the timing of the LDG in the Tasman Sea through the Neogene, and correlate changes in species richness to paleoceanographic events.

We used published planktic foraminiferal biostratigraphies from Deep Sea Drilling Program Leg 90 (DSDP) (Jenkins and Srinivasan, 1986) and Ocean Drilling Program (ODP) Site 806 (Chaisson and Leckie, 1993). These sites provide a transect from the equator to the southern Tasman Sea. Calcareous nannofossil datums for each site were updated to the Geologic Time Scale 2012 ages using recalibrated datums from International Ocean Drilling Program Expedition 371. Plankton occurrences were binned into 2 million year time slices to determine the timing of the LDG and changes in species richness through the late Neogene.

Generally, Miocene species richness is highest in the midlatitudes and tapers off towards the poles. During the Pliocene, there is a clear peak in richness in the mid latitudes, which quickly decreases in higher latitude sites. Our results indicate that planktic species richness was highest overall during the Miocene-Pliocene transition (6-4 Ma) at 21˚ S. In addition, species richness was highest at the mid latitudes during the same time interval at 31.5˚ S. This increase is concurrent with the Messinian Salinity Crisis, global cooling, and growth of Antarctic ice sheets, during which western boundary currents were thought to spin-up from increased trade wind strength due to increased equator to pole temperature gradients. Our results agree with previous studies, which found that a steep LDG from the mid latitudes to the poles developed by the Pliocene.
Silicate mineral weathering reactions by carbonic acid can act as a sink for atmospheric CO$_2$ if waters maintain a near-neutral pH. In contrast, pyrite weathering acidifies waters, thereby converting dissolved inorganic carbon species to CO$_2$ and potentially returning CO$_2$ to the atmosphere. This study investigates this idea by comparing the geochemistry of two, adjacent headwater catchments (~7.8 km$^2$) located in the Rowe-Hawley metamorphic zone. One catchment (Davis Mine Brook) receives acid mine drainage (AMD) from a small, historical pyrite mine, and the other catchment (Maxwell Brook) serves as a reference watershed. Both catchments are underlain by the Hawley Formation, a fine-grained feldspathic greenstone interbedded with amphibolite and schist. Bedrock in the Davis Mine Brook watershed is locally hydrothermally altered, and tailings piles containing pyrite and altered bedrock contribute acidity.

Water samples were collected in August and November, 2017, from streams and riparian groundwater seeps in glass bottles. Field pH was measured by inserting the probe through an O-ring cap on a bottle filled with sample to prevent degassing; field dissolved oxygen (DO) and specific conductance were also measured. Samples were analyzed for dissolved inorganic carbon (DIC), acid neutralizing capacity (ANC), major ions (Ca$^{2+}$, Mg$^{2+}$, Na$^{+}$, K$^{+}$, Cl$^-$, NO$_3^-$, SO$_4^{2-}$), Al$_{TOTAL}$, Fe$_{TOTAL}$, silica, $\delta^{18}$O, and $\delta^2$H. P$_{CO2}$ values were calculated from mass law equilibrium equations using DIC, field pH, and field temperature.

Preliminary results show that groundwater seep and surface waters affected by pyrite weathering have characteristic AMD geochemistry, with pH < 3.0, ANC < -4.0 meq L$^{-1}$ and highly elevated SO$_4$, Fe, and Al (up to 25.1, 7.3, and 3.5 mmol L$^{-1}$). In contrast, the reference watershed illustrates moderate alkalinity (mean pH and ANC are 6.54 and 0.2 meq L$^{-1}$) with low sulfate (~0.04 mmol L$^{-1}$). P$_{CO2}$ is 10-65% greater in acidic groundwater seeps than in surface waters for both Davis Mine Brook and the reference watershed. For all samples, elevated P$_{CO2}$ is supersaturated relative to the atmosphere, and it correlates better with low DO than with low pH, suggesting that dissolved gases in surface water exchanged with the atmosphere, releasing CO$_2$.
Analysis of Encrusters on a Pleistocene Coral Reef, Great Inagua Island, Bahamas, with Comparison to Encrusters on San Salvador Island, Bahamas

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Great Inagua and San Salvador Islands in the Bahamas provide outcrops of Pleistocene coral reef deposits of the Cockburn Town Member, Grotto Beach Formation (Eemian; MIS 5e). These outcrops are an important source of information regarding paleoenvironmental conditions and sea-level fluctuations during the last interglacial highstand, ~120,000 years before present. This research expands on the work we have conducted previously on Pleistocene coral reefs from San Salvador to analyze in detail the abundance, distribution and succession of various types of encrusters found on corals at two different locations on San Salvador Island with the analysis of two additional locations on Great Inagua Island.

Cockburn Town Fossil Reef (CTFR) on the west coast of San Salvador has in situ reef exposures. The top of CTFR is ~3 m above modern sea-level, and the reef is separated by an erosional discontinuity into Reef I and II. Reef I contains branching corals encrusted by red crustose coralline algae (RCC algae), foraminifera, stromatolites, and clotted microbialites, while Reef II corals lack thick encrustation. The Gulf (TG) on the southern coast of San Salvador features storm-deposited boulders containing corals with encrusters similar to those from CTFR. Well exposed on the western coast of Great Inagua is the top of Reef I as well as Reef II, separated by the Devil’s Point unconformity. Thick encrusters are generally not present, and the corals here have only up to ~3 mm thick coatings of RCC algae, foraminifera and serpulids, which represent typical taphonomic modifications. Devil’s Point (DP), on the west coast of Great Inagua, however, has an in situ Reef II exposure of Acropora palmata corals with up to 2 cm thick encrusters, forming an encrusted branching framework with irregular, bumpy exterior. The Marina (M) site, also on the west coast of Great Inagua in Matthew Town, is a spoil pile of boulders with corals encrusted by RCC algae, foraminifera, and microbialites of both laminated (stromatolites) and clotted fabrics, similar to those found on San Salvador. However, these encrusters are observed on domal coral Orbicella annularis.

Transition from coral to encrusting RCC algae to encrusting microbialites in samples from Reef I on San Salvador has been interpreted as a change in reef development from bank barrier to restricted backreef and lagoonal environments. The absence of thick encusters in the well exposed portions of Reef I at the Devil’s Point site on Great Inagua, with a notable exception of up to 2 cm thick crusts made predominantly of foraminifera, RCC algae, and serpulid tubes forming irregular bumpy exterior surface coatings on a large, in situ exposure of the encrusted branching framework in the lower part of Reef II, illustrates important differences between Pleistocene coral reefs on San Salvador and Great Inagua. The presence of microbialites on corals from displaced boulders in Matthew Town Marina on Great Inagua, however, reveals some similarities with reef encrusters from San Salvador. These observed similarities and differences warrant further investigation, which is unfortunately hindered by the lack of exposures of this stratigraphic interval in the Matthew Town area and may require collection of a drill core.
Surface and Deep Aquifer Communication in Shutesbury Massachusetts

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Shutesbury, Massachusetts is one of the small Hilltowns in western Massachusetts. Residents of Shutesbury do not have a centralized water supply and rely on individual, privately owned and maintained wells for access to potable water. These wells are maintained by a system of surface and deep aquifers that are in communication with one another through fractures in the bedrock. For this reason, the quantity and quality of groundwater in this town and the aquifer system as a whole is of prime importance to the residents of Shutesbury. The town itself provides a unique opportunity for extensive groundwater study. Geographically, it lies along the crest of a ridge with the aquifers’ primary recharge site where rainfall drains both west into the Connecticut River and east into the Quabbin Reservoir, the latter of which is one of the primary water supplies for the Greater Boston area.

The purpose of this study is to monitor communication between surface and deep bedrock aquifers within the town of Shutesbury Massachusetts. Over time, the study hopes to more comprehensively understand both seasonal fluctuations in the community water supply and aquifer recharge rates. In order to study this system, data from this study was collected from four well sites within Shutesbury. Each site included one deep well (100 or 400ft) and one monitoring well (under 20ft, to bedrock). Water temperature and levels were recorded using Onset HOBO U20L series data loggers and processed using HOBOware Pro graphing and processing software. Data was barocorrected with atmospheric pressure data collected from a local weather station in Shutesbury. Due to a technical failure of this weather logger, we were unable to collect weather data between 4:45pm on December
10, 2017 and 10:45pm on February 5, 2018. As a result, we were unable to barocorrect water levels within the wells during this approximately two-month period.

Figure 3. Pellham Hill Well Site #1: Both monitoring well (green) and deep well (mint) begin responding shortly after large rainfall events (blue arrow). However, the rate at which levels change varies with well depth. The deep aquifer is shown to recharge slowly over the course of the study, independent of daily water use cycles shown in monitoring well levels.
Abundance of Animals on a Sandy Seafloor in the Early Cambrian: Insights from the Lower Cambrian Poleta Formation

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The middle member of the lower Cambrian Poleta Formation, located in present day Esmeralda County, Nevada near the town of Gold Point, Nevada. The rocks in this section are important in that they record the critical interval of time after the Cambrian Explosion (English and Babcock, 2010) but before the early Cambrian extinction of animal reefs (Pruss et al., 2010). This window of time is crucial for understanding the benthic ecology and abundance of skeletonized organisms during the interval preceding the later collapse of the archaeocyaths. The Poleta Formation was deposited along a marine shelf undergoing a series of transgressive-regressive cycles. The upper and lower members formed during lowstand and are dominated by carbonates (English and Babcock, 2010). The middle member formed during transgression and highstand, producing a heterolithic facies that includes siliciclastics (English and Babcock, 2010; Nelson, 1962). These mixed carbonate-siliciclastic facies offer the best surveyable preservation of the benthic fauna that existed at the same time as archaeocyaths, but in different environments. Grain abundance can reveal changes in the dominant organisms as well as environmental changes or disturbances. The small-scale patterns or trends identified in the middle member will contribute to a larger examination of trends seen in the Poleta Formation and lower Cambrian ecology as a whole.

After dissolution of eleven samples in dilute acetic acid, we determined that fossil grains were both more abundant and more diverse at samples collected closer to the lower contact with the carbonate-dominated archaeocyathan reef. These basal samples contained a greater volume of unidentifiable small shelly fossils as well as dominant trilobites, echinoderms, possible agglutinated foraminifera, possible sponges, and chancelloriid sclerites. Samples collected furthest from the reef contained fewer unidentified small shelly fossil grains and much fewer other fossils. For all samples, trilobite and echinoderm preservation was almost exclusively replacement by apatite. Possible sponges in all samples were preserved mostly by silicification. Iron-oxides and dolomite were also found as mineral grains and as possible fossil replacement minerals. While this part of the Poleta Formation is largely siliciclastic, these results indicate that there exists a largely unexplored benthic ecology in the middle member of the Poleta Formation after deposition of the carbonate reef. Both this newly discovered diversity and taphonomy in the Poleta Formation warrants further investigation.

References:

Agriculture is synonymous with our civilization- it is one of the most fundamental ways society interacts with the environment. Soil, especially healthy soil, is essential to maintaining the ability to provide food for a growing global population as well as acting as an important sink in the global carbon cycle. This research explores how human interaction, primarily agricultural practices, and erosion are affecting soil organic carbon (SOC) in cultivated soybean-corn crop rotation fields compared to native prairies. Analysis shows that prairies have an average $\delta^{13}C$ value of -18.6‰, while the signature of cultivated fields is -22.7‰. In the fields, 35-54% of the SOC was input by domestic crops and the carbon concentration had decreased by an average of 40%. Carbon sources were determined via soil carbon concentration measurements and carbon isotope mixing models. The influence of hillslope curvature was also examined using modeling. Hillslope curvature values suggest that the field’s morphology may not have a large influence on $\delta^{13}C$, but likely influences the decline of carbon concentration. By understanding the isotopic composition of SOC and the effect hillslope curvature has on it, we can move toward developing an effective tool to further the understanding of how soil organic carbon, a vital nutrient, cycles through agricultural landscapes.
Determining protolith and metamorphic grade for biotite-garnet gneiss in the Ruby Range, SW Montana
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Biotite-garnet gneiss (BGG) found in the Precambrian Dillon Gneiss of the Ruby Range (southwest MT) likely had pelite, dacite, or rhyolite as its protolith. While these results are not definitive, whole-rock geochemical analysis (both major elements by XRF and trace elements including REE by ICP-MS) done on nine samples and the resulting immobile trace element diagrams, TAS diagram, and graphs comparing samples to geochemical analyses of sedimentary rocks all strongly suggest these possibilities.

The fifteen samples originally selected for analysis were collected from a 3 km transect along Cottonwood Creek Road. Twelve out of the fifteen samples were made into thin sections for petrologic study and SEM analysis. Three samples from one locality (17-RG-14A, 17-RG-14B, and 17-RG-14C) were selected to study in detail due to their interesting migmatitic relationships and the fact that they contain corundum, spinel, and sillimanite in addition to biotite, garnet, and feldspar. Focusing on sample 17-RG-14C (referred to as the super BGG), a petrogenetic grid involving the NaKFMASH system (adapted from Spear and Parrish, 1996) has been used to constrain metamorphic conditions to pressures of approximately 0-9 kbar, and temperatures in the range of 650-950ºC.

Although some sections of the Ruby Range have been closely studied, the Dillon Gneiss has been neglected because it is a complex, undivided suite of rocks that is volumetrically dominated by quartzofeldspathic gneiss. Ultimately, the goal is to understand what continental dynamics were in motion in Laurentia during the time of gneiss metamorphism. With this information, understanding how continents are created and then grow from the amalgamation of smaller bodies can continue to expand.
Impact of Hurricanes and Sea-level Rise on Small Island Nations: Examples from The Bahamas

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This project relates historical satellite imagery to the information about intensity and pathways of hurricanes in The Bahamas to assess amount and style of modifications by major storms during times of globally rising sea levels. Examples include severe beach erosion, damage to roads, washover of beach sand and rock boulders into interior marshes, and conversion of coastal lakes to lagoons due to the creation of new inlets. This project specifically evaluates the usefulness of Google Earth historical imagery for documenting hurricane impact on Bahamian islands.

Our focus was on seven major hurricanes that impacted The Bahamas during the time period of Google Earth coverage, i.e., from 2001 to present day: Frances (2004), Ike (2008), Irene (2011), Sandy (2012), Joaquin (2015), Matthew (2016), and Irma (2017). Google Earth imagery of all islands impacted by these hurricanes was examined, and some of the most impressive examples from hurricanes Ike, Joaquin, Matthew and Irma on San Salvador and Great Inagua islands are documented and supplemented by field photos and high-resolution drone images.

Google Earth images proved to be a useful tool for such documentation, but high resolution images taken at times immediately after major hurricanes commonly were not made. Such images are needed to document maximum hurricane impact in these areas before they start recovering by natural and human-assisted processes. High-resolution drone images are particularly useful in this case, but they are expensive to acquire and their collection is dependent upon the ability to travel to the impacted areas in a timely manner after major storms. Overall, the results represent important documentation for communicating information about vulnerability to hurricanes and sea-level rise with local residents, developers, and other decision- and policy-makers of small island nations.
Examining the Unusual Geological Conditions in Shark Bay, Australia

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This project contains an analysis of sand grains from Shark Bay, western Australia. In Shark Bay, a UNESCO World Heritage site, and one of the few places in the modern where stromatolites accrete, carbonate sand grains consist largely of foraminifera and ooids. Sand from 4 points in an onshore-offshore transect, and 4 positions along a beach transect were sampled and sieved into 6 size fractions: >841, >595, >420, >250, >180, and >149. After sieving, each sample was examined for the dominant components. In particular, in the smallest size fraction, a series of unusual minerals and blackened foraminifera were found. The mineral grains produced EDS peaks of S, Fe, Cu, and Ti. The foraminifera showed Si, O, and Mg in addition to common Ca and C under EDS. Our preliminary conclusions suggest that grain size distribution measurements, SEM imagery, and element analyses can provide insight into the depositional conditions of Shark Bay.
The Oxford County pegmatite district of southern Maine hosts nearly all of the complex, LCT-type (lithium-cesium-tantalum) pegmatites in New England. This study focuses on water concentrations of nominally anhydrous minerals (NAMs) in the Mount Apatite and Berry-Havey pegmatites of Oxford County, Maine. NAMs can host several hundred ppm to more than 1 wt.% water in their crystal structures, depending on the type of mineral. Water contributes to the growth of large crystals in pegmatites. The goal of this study was to measure water concentrations in three types of NAMS (quartz, feldspar, and garnet) from the pegmatites and to 1) evaluate the range of variation in water concentration within crystal species in each pegmatite and 2) calculate the water concentration in the parent melt on the basis of distribution coefficients for water between the mineral and the parent melt. Fourier transform infrared (FTIR) spectrometry was used to measure water concentrations on 230 targeted points, including transverses across garnet, feldspar and quartz crystals in thick (~100 micron) sections. A variation of the Beer-Lambert equation:

\[ C \text{ (wt.} \% \text{H}_2\text{O)} = (1.8) \frac{\text{Absorbance}}{\text{thickness} \times \text{density} \times \text{molar absorption coefficient}} \]

was used to calculate water concentrations. Water concentrations in feldspar exceed 1 wt. % in both pegmatites. Garnet crystals show even higher H\text{O} concentrations above 1-2 wt. %. This phenomenon likely relates to hydrogarnet substitution where (OH)\text{4}^\text{4-} substitutes for SiO\text{4}^\text{4-} in the garnet structure. Further microprobe analyses are currently being conducted to confirm this hypothesis. In this study, values from the Beer-Lambert equation were then multiplied by 3 following Libowitzky and Rossman’s (1996) analysis of the geometry of beam interaction with crystalline solids, suggesting significantly higher H\text{O} concentrations than those shown in past studies. A crude estimation of the water concentration within the original pegmatite melts of the Berry-Havey and Mount Apatite pegmatites was calculated on the basis of the distribution coefficient for water between feldspar and melt (D = .0004, Johnson, 2006) which yielded 55.17% (g/g) and 55.75% (g/g) water, respectively. These values are, surprisingly, consistent with water concentrations of pegmatite parent melt based on melt inclusions (Thomas and Davidson, 2012).
Radiation Halos in Kyanite around Actinide-Rich Compositionally-Zoned Florencite, Dora Maira Massif UHP Whiteschist

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In this study, we looked at an ultrahigh-pressure (UHP) whiteschist from the Dora-Maira Massif in the Italian Western Alps. While studying this whiteschist, several ~10-20 µm grains of a Light Rare Earth Element (LREE) Aluminum Phosphate were found inside a ~2.5mm Kyanite grain using a Scanning Electron Microscope. Through spectral analysis, we find that this LREE Aluminum Phosphate is the mineral Florencite, nominally (LREE)Al₃(PO₄)₂(OH)₆. While looking closer at these Florencites, they were found to exhibit marked compositional zoning. Some examples may be novel variants within Florencite compositional space. Using BSE and Energy-Dispersive X-ray Spectroscopy (EDS) on the SEM, we found that the Florencite grains all showed a clear core and outer rim, and other phases very bright in BSE. Spectra of the relative abundance of many elements were taken using EDS. Moving from the core of these grains to the rim, we saw a sharp drop in LREEs such as Ce, La, and Nd, along with a sharp rise in Si, Pb, Ca, Th, and U. The compositional difference between the core and an unusual bright phase is even more extreme. Here, we see the LREE abundance drop to a fraction of the abundance found in the grain cores, and the relative abundance of Th and U reach many times the abundance in the core. In the bright phase in one Florencite grain, the Th and U relative abundance was found to be nearly three times larger than the Al abundance.

Each of these composite Florencite grains is surrounded by spherical halos of structural damage in the Kyanite from the bombardment of alpha particles emitted from the decay of Th and U. These halos of damage are visible in cathodoluminescence (CL). Around the Florencite grain with the highest relative abundance of Th and U, and with a small BSE-bright phase with extremely high U and Th, we can clearly see several concentric rings in CL. These concentric rings appear to have a consistent spacing around the various actinide-rich inclusions in the Kyanite, and appears to correspond to the different energies of various alpha-emitting steps in the Thorium and Uranium decay series. A faint outermost ring seen in the best examples would then correspond to either the decay of $^{214}$Po to $^{210}$Pb in the Uranium decay series, or the decay of $^{212}$Po to $^{208}$Pb in the Thorium decay series, which are both the highest energy decays in their respective series (1, 2). We are not certain which isotope of Polonium is responsible for this outer ring, since there may be a ring even further out which we cannot detect. Further research is needed to understand the compositional zonation of the Florencite, and to characterize and understand the high U, Th, and Pb accessory phases, as well as the radioisotopes responsible for each ring of lattice damage in the host Kyanite.

References:

Postcranial Anatomy of a New, Well-Preserved Specimen of the Dinosaur
Dryosaurus altus (Ornithischia, Dryosauridae) from Albany County, Wyoming

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The ornithopod dinosaur Dryosaurus altus is a small herbivore known from the well-studied Morrison Formation of the North American Late Jurassic, which was deposited in an environment dominated by giant sauropods where smaller herbivores seem to have been comparatively rare. Although Dryosaurus is the best-known member of the ornithopod family Dryosauridae, most specimens are fragmentary, and the Dryosauridae as a whole is not a particularly well-studied family of dinosaurs. The “Middleton Dryosaurus,” donated to Amherst College from a private collection in 2013, is a very well-preserved individual collected from the East Camarasaurus Quarry in southeastern Wyoming, in the Kimmeridgian-aged Brushy Basin Member of the Morrison Formation. This specimen is minimally distorted and preserves a considerable amount of the skull and postcranial skeleton. Three cervical vertebrae, five dorsal vertebrae, the sacrum and pelvic girdle, 24 caudal vertebrae, several ribs and chevrons, both forelimbs (except the mani), and both hindlimbs are completely or partially preserved; the right hindlimb is especially well-preserved, as all elements except one pedal phalanx and one distal tarsal are present and most are complete.

Anatomical description of the postcranial skeleton of the Middleton Dryosaurus provides additional information that is useful to understanding this genus and other members of Dryosauridae. The high-quality preservation of this specimen has allowed confirmation of caudal vertebrae characters (neural spines at >45 degree angle relative to centra on the anterior caudals; short neural spines on posterior caudals) that can be used to diagnose autapomorphies in other dryosaurid taxa. Additionally, the Middleton Dryosaurus includes many elements found only rarely and/or incompletely in other Dryosaurus altus: all six sacral vertebrae, a complete scapulocoracoid, a complete radius and ulna, and a nearly-complete pes. Overall, the Middleton Dryosaurus is similar to other, generally less-complete, specimens of Dryosaurus altus; however, it seems most similar in form, size, and appendicular proportions to other specimens collected from approximately coeval sites in the same region of southeastern Wyoming, suggesting that Dryosaurus altus exhibited geographic and/or temporal variation throughout the Morrison Formation. Despite general similarity, the Middleton Dryosaurus appears to differ from other known specimens in the degree of fusion of its scapulocoracoids and the neurocentral sutures on its dorsal and caudal vertebrae, suggesting that it was skeletally mature, despite its moderate size.

This initial examination of the excellent postcranial skeleton of the Middleton Dryosaurus provides new implications for variation within Dryosaurus altus, as well as useful new comparative material, especially the caudal vertebrae and appendicular skeleton. Furthermore, the amount of skeletal fusion observed in this specimen indicates it may represent a previously-unknown stage in dryosaurid growth series, and is important in understanding the life histories of these dinosaurs. The Middleton Dryosaurus clearly represents a valuable resource for further study of the Dryosauridae.
Stratigraphy and Geochemistry of a Fond St. Jean Cinder Cone, Dominica

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Dominica is an independent island nation located in the central portion of the Lesser Antilles Island arc, a magmatic arc that results from subduction of the South American Plate beneath the Caribbean Plate (Smith et al. 2013). Subduction in this setting promotes partial melting of the mantle, producing magma that ultimately rises to the surface of the earth and erupts through variable styles of volcanism. Magmas may pond and differentiate on the way to the surface of the earth, resulting in deposition of chemically distinct rocks. Dominica is primarily composed of the intermediate rocks andesite and dacite, though a single eruptive center in the southeast, Foundland Center, is composed predominantly of mafic basalts. Previous work (Smith et al., 2013; Wills, 1976) indicates that air fall samples collected at Fond St. Jean, a town within Foundland Center, are the most mafic samples collected on the island, and therefore potentially represent the islands least evolved rocks on record.

This study analyses additional basaltic samples from a partially eroded cinder cone in Fond St. Jean. Techniques including inductively coupled plasma optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS), as well as petrographic analyses and solid-melt modeling were used to analyze the mineralogy and textures of these samples, styles of volcanism that erupted them, and determine a potential composition of the mantle from which these rocks were derived. Additionally, field observations, elevation measurements, and thicknesses of units composing the cinder cone were used to construct a stratigraphic section through the volcano.

Field relationships and alternating textures of volcanic material imply changes in volcanic styles through time. Petrographic textural analyses indicate that both explosive and effusive volcanism contributed to the cinder cones formation. Additional petrographic analyses indicate that while mineralogy is consistent throughout the cinder done, minor zoning implies slight crystal fractionation within a magma chamber. Discrimination diagrams show major and trace elements for these samples are consistent with the expected chemistry of island arc basalts, making them good candidates for modeling mantle melting. 5-15% melting of a garnet free lherzolite mantle fits the data for these samples best, and trace element ratios indicate that sediment incorporated into the subduction zone contributed to the chemistry of the mantle melt.

Investigating Sediment Loading into America’s Largest Municipal Water System

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Sediment concentrations in New England waterways have been increasing throughout the past 40 years. Here we contribute to an ongoing study by the USGS and the New York DEP that looks to identify various sources of turbidity within the Ashokan Reservoir’s watershed located in the Catskill’s of New York. Results of this study will help water managers prioritize the siting and selection of stream management projects that maximize efficiency towards reducing turbidity in this region’s water system. Methods involve analyzing four sediment cores collected at the Ashokan Reservoirs’ west basin. Through evaluation of flooding events, precipitation records, temperature records, and other environmental factors that affect the rise of turbidity, causes and projections have been determined.
Assessing the potential use of microtraces of gastropod predation as a diagnostic for predator-prey interactions in the fossil record

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Abstract
Predatory gastropods have left signs of boring predation in the fossil record as early as the Cambrian (McMenamin and Schulte McMenamin, 1990). Through studying drill holes in prey, we can better understand predator-prey interactions in marine communities. It has been proposed that further study of the interior of drill holes yields microtraces left by the radular teeth during the drilling process (Schiffbauer et al., 2008; Tyler and Schiffbauer, 2012). The pattern and orientation of the traces can be used to associate predator with prey and act as a diagnostic feature to identify the predator.

Trace fossils can provide great insight into past environments, but only when they are well preserved. Through assessing one hundred and eighty drill holes using scanning electron microscopy, I offer evidence suggesting the limited presence of predatory microtraces. Interpreting shell deterioration and extrapolating the observed degradation of modern specimens to hypothetical paleoenvironments suggests that preservation of such minute traces would be poor and would thus negate the purpose of creating such a diagnostic. Additionally, the current understanding of the drilling process suggests that the preservation of microtraces within the drill hole margins is an infrequent occurrence. Before utilizing their radular teeth, predatory gastropods deploy secretions from the accessory boring organ (ABO) to break down the shell surface, lessening the preservation of predatory microtraces (Carriker, 1969). This study has discovered porcellaneous rims surrounding the drill holes in the Miocene Saxolucina. Further study into these rims may provide additional insight into the drilling strategy of naticid gastropods.

Detailed analysis of an early Cambrian reef, upper Harkless Formation, Esmeralda County, Nevada

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The early Cambrian is a dynamic time during which the Cambrian Explosion is just underway (Marshall, 2006), and the first complex ecosystems are becoming established. Archeaocyaths are an extinct group of marine sponges and were the first calcifying metazoan reef builders in oceans dominated by microbial reefs (Rowland and Shapiro, 2002). They appeared first in the early Cambrian, and the Harkless Formation is of particular interest because it spans part of this early Cambrian interval in the rock record 40 million years before calcifying metazoan coral reef builders radiated in the Ordovician. Furthermore, it is either during Harkless time or just after that the archaeocyaths disappear entirely, marking the end of the first wave of animal reef building in the Paleozoic. The goal of this research is to quantify the abundance of skeletal organisms in the thin sections from a series of patch reefs in the upper Harkless Formation to determine the nature and abundance of reef building organisms in these and to provide some environmental context for their formation. It is also particularly important to focus efforts here, as these likely represent the last gasp of reef building in the early Cambrian in the western US.

References:

Time Zero: Baseline Soil Analysis at Tidmarsh from Cranberry Farm to Future Wetland
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The total land area for wetland and estuaries in coastal Massachusetts has decreased significantly over the last 100 years due to climate changes, environmental changes, and commercial development. One such land-use change is the transformation of a large percentage of the region’s wetlands into cranberry farms. However, with the demand for Massachusetts cranberries diminishing, many farms are being restored to their natural wetland state. Unfortunately, most restoration projects include little data collection and long-term monitoring.

Tidmarsh Farms, in Manomet, Massachusetts, cultivated cranberries for over 100 years, and is now in the process of a restoration design that includes removing barriers to water flow, increasing soil organic content in the shallow root zone, and generating variability in topography. Ideally, these actions will result in diverse microclimates and increased surface soil moisture that will provide a habitat more likely to encourage the growth of a wide variety of wetland plants and other native species (UMass Center for Agriculture, Food, and the Environment, 2017).

To make sure that restoration goals are met, it is necessary to make quantifiable observations to monitor the progress. We conducted baseline monitoring on 3mx3m vegetation plots at 71 locations collecting 30cm-deep sediment cores at each plot. Cores were divided into increments of 5cm and 10cm. The moisture content, soil organic content, Fe, N, Ca, and Mg will all be measured for each sample. The goal of this analysis is to map the distribution of soil chemistry, texture and water content with depth and compare these conditions pre-restoration to post-restoration. We also compare the surface soil moisture values to those measured with a soil moisture probe. Together, these data should provide a baseline site characterization so that progress can be tracked with long-term monitoring as the wetland is restored.
Relative Abundance of Calcifying Metazoans in the Nama Group

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This research aims to explore the ecological significance of three calcifying metazoans in reefs in the Nama Group from the Ediacaran Period by determining the abundance of these metazoans in stromatolite and thrombolite build-ups. A total of 27 thin sections were point counted from three reefs: HR16, OR216, and F1618. The data compiled from point counting the thin sections were used to determine the abundance of these calcifying metazoans in each of the three different reefs and within the fabrics of the reefs. The average percentage of total fossils in each fabric present in the reef were graphed to compare fabrics within each reef and between reefs. We found that, in general, in thrombolitic build-ups, skeletons account for 2.2% of points counted, in contrast to stromatolites (1.5%). The grainstone fill between and in the interstices of the mounds had 5.7% on average. The results from the reefs HR16 and F1618 support the hypothesis that thrombolitic fabrics are intimately related to animals and stromatolitic fabrics tend to have less skeletal material present. The calcifying metazoans are more prevalent in the thrombolitic fabric than in the stromatolitic fabric, and were also abundant in the fill between the mounds. Future work will continue to explore the relationship between fabric type and presence of calcifying metazoans, looking more closely at the environments within each reef site and the conditions that would have existed to make the calcifying metazoans more or less abundant.
Sedimentary Geochemistry of the Lower Triassic Montney Formation, British Columbia

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The Lower Triassic Montney Formation of the Peace River Basin, British Columbia, is a complex succession dominated by siltstone and sandstone with shale and bioclastic packstone occurring in some areas. The facies in the Montney Formation represent a wide variety of depositional environments, ranging from middle to upper shoreface sandstones, middle to lower shoreface sandstones, and coarse siltstones, as well as finely laminated siltstones and turbidites. The Montney Formation records sediment accumulation on the northwestern margin of Pangea during the first 5 million years after the Permian-Triassic mass extinction.

Delayed earth system recovery after the Permian-Triassic mass extinction is often attributed to marine anoxia. However, the extent of marine anoxia and the influence of global versus local drivers remains poorly constrained. This study aims to further evaluate the role of anoxia, euxinia, and ferruginous conditions during the recovery period after the Permian-Triassic mass extinction. Geochemical analyses were completed on 395 m of core through the Montney Formation, including total organic carbon (TOC), pyrite sulfur contents, iron speciation, and major and minor elemental compositions. These proxies, used as signals of shifting redox conditions, can be used to interpret the depositional environment.

Stratigraphic trends of iron proxies show that the Montney Formation was deposited under persistent anoxic conditions. These geochemical data also suggest that redox conditions shifted towards euxinic conditions at 3 intervals: after the PTB, during the Smithian-Spathian boundary and the at the beginning of Lower Anisian.
Evidence from Zircon Crystal Morphology of a Complex History for the Middle Tertiary Atascosa Lookout Lava Flow, Southern Arizona

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The Atascosa Lookout Lava Flow is the uppermost layer of a middle Tertiary (26-23 Ma) volcanic complex located in the Atascosa Mountains in southern Arizona. The flow is a trachyandesite and contains enclaves and crystal clusters of various compositions. It is likely that the magma represented by the lava flow sampled materials that equilibrated at a range of crustal levels, possibly in secondary magma chambers. We analyzed zircon crystals found in the Atascosa Lookout lava flow to test the hypothesis that distinctive zircon morphologies might be characteristic of different settings in the flow (i.e., as inclusions in specific minerals inside or outside of crystal clusters, in enclaves of contrasting compositions, or as independent matrix crystals. We used a scanning electron microscope with both backscatter electron and cathodoluminescence imagining abilities to complete the study. In all of the samples, zircon crystals occur in a variety of settings in these rocks, including being isolated in the groundmass, inside of enclaves, and in crystal clusters. While the sizes of the zircon crystals varied from about 1 micrometer to 20 micrometers, many of the larger zircon crystals with well-defined zoning were found inside of magmatic enclaves. Zircons in the rock matrix and in crystal clusters showed a much more uniform range of crystal sizes and more pronounced zoning. This possibly suggests that these settings host zircon crystals preserving a large variety of ages of crystallization. U-Pb dating of the zircon crystals at the University of Arizona Laserchron laboratory in June, 2018 will test this hypothesis.
Zircon Morphology and the Origin of the 2.6 Ga Fehr Granite, Athabasca Granulite Terrane, Northern Saskatchewan

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The Athabasca granulite terrane (AGT) of northern Saskatchewan provides approximately 20,000 km² of exposure of the lower crust. The eastern part of the AGT region is composed of two major units, the Chipman tonalite batholith (3.3 Ga) and the Fehr granite (2.6 Ga). Two samples of the Fehr granite were studied with the goal of correlating granite microtextures and zircon characteristics with crystallization conditions. The use of cathodoluminescence and back-scattered electron imaging on the scanning electron microscope (SEM) allowed us to closely analyze the internal crystal zoning areas, providing information on the magmatic history recorded by the zircon crystals. Zircon crystals in the Fehr granite in general were found to be dominated by CL-dark zones, generally correlated with growth from relatively U-poor melt. The complexity of zoning in zircon crystals in the Fehr granite indicates multi-stage and complex magmatic/metamorphic history. Large zircon crystals show significant radiation damage. The radioactive decay process has resulted in volumetric expansion and metamictization, the disruption of the crystal structure of zircon as a result of radioactive decay. The Fehr granite, despite showing little evidence for alteration in field exposures, was exposed to hydrothermal events that are recorded in zircon textures. This process of characterizing microtextures in zircon crystals before a geochronology study is carried out is crucial to yielding accurate dating results.
Zonation of Slow Slip and Coupling along the Cascadia Subduction Zone

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Stress accumulates along subduction zones as tectonic plates converge, and is released by earthquakes. The Cascadia subduction zone, which extends from Northern California all the way to Vancouver Island, hasn’t seen a major earthquake since 1700. However, slow slip events have been detected on the subduction interface. Slow slip events are aseismic slip events that take place over several weeks to months, rather than the seconds to minutes duration of an ordinary earthquake. We want to understand the effect these slow slip events have on slip deficit on the Cascadia subduction zone.

Using GPS data as well as an optimization algorithm we were able to visualize the spatial distribution of slip deficit and slow slip. The optimization algorithm used is a total variation regularization (TVR) algorithm. TVR is a process that minimizes the number of unique values of coupling on the subduction zone. The algorithm therefore establishes spatial clusters of discrete coupling values, with abrupt variation in the coupling value between clusters. This resulted in a zone of slip deficit in the shallow portion of the subduction zone, with slow slip events that occurred further down-dip with some or no overlap.

By subtracting the slip from the slow slip events from the cumulative slip deficit, we were able to see the effect of these events have on slip deficit. Indeed, even with the small amount of overlap, the slip from slow slip events erodes the slip deficit. This is significant because it indicates that slow slip events help release stress along the subduction zone without the occurrence of an earthquake.

References:


The Impacts of Seawater Encroachment on Sediment Microbial Mercury Methylation in a Connecticut River Embayment

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Hamburg Cove, a tidal embayment off the Connecticut River, contains high concentrations of inorganic mercury in the sediment that is sourced from 20th century industrialization in the Northeast. This legacy mercury pollution may be subject to microbial methylation, transforming it into its most toxic organic species. Hamburg Cove is situated close enough to Long Island Sound that it experiences daily tidal influx, and as such, contains a range of salinities in the water column and in the pore waters within the sediments. Microbial mercury methylation potential was investigated in two sites; first, in the deep, central area of the cove where tidal seawater collects, and second, in a shallower, freshwater area of the cove. Both sites have a similar total mercury concentration of ~200 ppb in the top sediment layers; however, at the saline site the top 9 cm of sediment maintains a methylmercury concentration of 1.4 ppb, whereas at the fresh site the methylmercury concentration begins at 1.62 ppb, but by 3 cm starts to decline and by 6 cm is as low as 0.38 ppb. Pore water analysis shows that the deeper site is 15-times more saline than the fresh site. The higher salinity leads to more sulfate in the pore waters to greater depths, and far more production of bicarbonate. Both trends suggest greater activity by sulfate reducing bacteria, the microbes found to commonly methylate mercury. In sum, these data demonstrate that the saline site in Hamburg Cove has more favorable conditions for sediment microbial activity, resulting in higher levels of sulfate reduction and higher levels of methylmercury to greater depths. Projected sea-level rise will increase the seawater encroachment on Hamburg Cove, thus increasing the deep saline area and potentially driving higher levels of microbial activity and sediment methylmercury.
Soil organic carbon accumulation in northeast Kansas restored prairies

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Agricultural land use can degrade soil and reduce the global pool of soil carbon. The loss of soil organic carbon (SOC) reduces soil fertility and may contribute to the rising atmospheric carbon dioxide levels, thus, negatively impacts humans. Restoring degraded soils can increase fertility and offset greenhouse gas emissions. We investigated SOC accumulation in restored prairies in the Midwestern United States to gain insight on the behavior of carbon accumulation in this region. SOC measurements in farmland, restored prairies, and native prairies in northeast Kansas were used to address SOC reduction due to farming, and SOC accumulation in decade to half century old restored prairies. Soil samples were collected in 0-20 cm and 20-40 cm depth increments, and inorganic carbon was removed by acid fumigation prior to SOC measurement using an elemental analyzer. The SOC in the agricultural field was 58% and 50% lower at 0-20 cm and 20-40 cm depths respectively relative to native prairie. The SOC reductions demonstrate agriculture’s negative impact on fertility. Results show SOC content is positively correlated with time since restoration after accounting for an outlier (R^2=0.85 for 0-20 cm depth, R^2=0.59 for 20-40 cm). Factors including land use management, vegetation, rill erosion, and topographic gradient and curvature would be worth researching in order to gain more insight on carbon accumulation rates in Midwest soil.
Rowland’s Reef is a 70 meter thick reef full of archaeocyaths at their peak from the Cambrian Period (~530 Ma) found near Gold Point, Nevada. Rowland’s Reef has been studied extensively, but the Poleta Formation preserves another 70 meter-thick reef less than 100 km away, and this reef has not been studied extensively. As some of the largest animal reefs of the Cambrian, the reefs of the Poleta are of particular interest. These reefs are built primarily by a consortium of archaeocyaths (extinct sponges) and microbes. The newly discovered reef was sampled every 1 to 2 meters in the field in May 2017. This year, by counting two hundred points in 33 total thin sections from the Poleta Formation, the diversity of fossils found can be analyzed and recorded, in order to compare to the abundance of archaeocyaths found in other reefs from this time. Our preliminary analysis reveals that the lower part of the reef contains fewer archaeocyaths than the upper part of the reef, suggesting an ecological zonation similar to Rowland’s Reef. The diversity of total reef organisms, however, is lower than the patch reefs of the overlying Harkless Formation. Further work will focus on uncovering the paleoecology of these first animal reefs.
Post Application Concentrations of Salt in Snowbanks and Streams of Shutesbury, Ma.

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Road salt is used widely today as the deicing agent that allows safe travel on our roadways. Despite its effectiveness in leaving roads free of ice, there are many concerns as to what happens to all the salt that is applied and where exactly it is ending up. Mount Holyoke’s Applied Environmental Geology class, led by Alan Werner, Professor of Geology, investigated the conductivity related to salt buildup and runoff in snowbanks and streams in Shutesbury, Massachusetts and the surrounding area. Conductivity measures water’s ability to pass electrical current and this ability is directly related to the concentration of ions in the water. These ions can come from dissolved salts as well as inorganic materials. Data from snowbanks shows high values of specific conductivity across town lines and on both sides of the roadways. Additionally, stream logger data, viewed with HOBOware, also shows spikes in conductivity levels at sites across two streams, typically corresponding with temperature spikes above freezing. The information presented here also expresses the relationships between conductivity and moles of NaCl and the levels of salt needed to produce adverse effects on plants.

Figure 1. (top) Comparison of specific conductivity between salt and materials used on roadways as deicers and traction enhancers—Enhanced salt, 50/50 sand-salt mixture, sand with 10% salt added (called sand-minimal salt on graph), Sand only.

Figure 2. (bottom) This graph shows the relationship between specific conductivity and moles of Sodium chloride.
Benthic Foraminifera of Shark Bay, Australia: What modern sand can teach us about climate, environment, biodiversity, and water chemistry

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Foraminifera are protists that secrete calcite (CaCO$_3$) shells or ‘glue’ grains of sand around their single celled bodies. In a recent field season in Shark Bay, Australia, a set of sand samples were collected from 4 points along an onshore-offshore transect in a subtidal setting near stromatolites of Carbla Point and from 4 points along the beach. The sand was collected to examine ooids, but it was discovered that benthic foraminifera make up between 5% and 30% of sand samples contributing significantly to the carbonate production in that region. Whereas most tests preserve morphological details, many grains are coated, eroded and the mineralized foraminifera preserve black authigenic minerals inside their chambers. Between 19 and 21 species of benthic foraminifera have been found in these samples, but the most abundant species being *Peneroplis planatus* and *Peneroplis peneroplis*. The diversity and abundance of these organisms varies quite a bit between samples. Of the mineralized grains, the smallest fractions (<250um) have the greatest abundance of black authigenic minerals. Preliminary SEM and EDaX analysis of a few specimens revealed abundant Fe and S peaks in these minerals, suggesting that the mineral precipitating within the foraminifera chambers is pyrite. Pyrite typically precipitates out of solution in low oxygen conditions, indicating that the pore waters in which these foraminifera are bathed after death experience fluctuating oxygen levels. Even in the heavily pyritized tests that now appear as black, EDaX analysis indicates that the outside of the shell contains abundant high-Mg carbonate. This result suggests that the originally secreted calcite remains intact after death. The goal of this study was to 1) to characterize the diversity and abundance of benthic foraminifera in each of the 8 samples; 2) to dissolve a subset of foram tests that contain the black minerals to better constrain the minerals growing authigenically in their chambers; and 3) examine those minerals under SEM and EDaX to confirm their composition. By counting subsets of the samples, I created a reconstruction of the diversity and abundance of foraminifera along a depth transect to see if environmental parameters influence diversity. In the future I hope to better constrain the growth of authigenic minerals in the tests to determine if these tests are experiencing low-oxygen conditions after death but prior to lithification. Pyrite formation in coarse sandy sediments would be surprising in an apparently well-oxygenated depositional environment and would require further investigation.