COLORADO COLLEGE

GEO DAY 2024

Geology Department Research Symposium

MARCH 30, 2024
BLOCK 7 - FIRST SATURDAY
8:30 AM

TUTT SCIENCE
COLORADO COLLEGE
1112 N NEVADA AVE.

PROGRAM

Speaker Session - 9:00 to 10:25 AM

8:30 AM - Breakfast Buffet

9:00 AM - Welcome Statement

9:05 AM
Pierce Hayton -
The Role of Fault Damage Zones in Structurally Controlled Landscape Evolution, Sevier Fault Zone, Southern Utah

9:25 AM
Emma Revenaugh -
Reconstructing Nitrogen Dynamics in Three Minnesotan Lakes Using Stable Isotope Ratios of Nitrogen

9:45 AM
Katya Nicolayevsky -
A Carbon Isotope Investigation of Fossil Leaves from Corral Bluffs

10:05 AM
David Mims, Galileo Defendi-Cho, Tirso Jesus Lara Rivas -
XRD & Raman Spectroscopy of Serpentinite Minerals from Nelson, New Zealand

10:25 AM - Open Q&A to Speakers

PROGRAM

Poster Session - 10:25 AM to 12:00 PM

10:25 AM

Annie Breyak -

Investigating Tourmaline-Mineralized Mirrored Brittle Faults in Western Antarctica for Seismic Signatures

Harold Oppenheim -

Study of Two Clastic Rock Types Sampled from Glacial Erratics in the Ford Ranges of West Antarctica

Charlie Hite -

Using GIS to Reconstruct Colorado's Paleoenvironments

Ilene Kruger -

Variations in Crystallographic Preferred Orientation within Different Rock Types in the Talkeetna Arc, AK, and Analog Deformation Experiments

Jake Hams -

Constraining the Temporal Onset of Laramide-style Tectonics with Monazite and Apatite U-Pb Geochronology

12:00 PM - Smooth Move award and Announcements

12:15 PM - Closing Statement

4:30-7:30 PM - The Barbecue

920 N Wahsatch
(Baxter's house)

ABSTRACTS

The Role of Fault Damage Zones in Structurally Controlled Landscape Evolution, Sevier Fault Zone, Southern Utah

Pierce Hayton
Advisors: Dr. Tyler Grambling, Colorado College
Dr. Sarah Schanz, Colorado College

The relationships between fault systems, weathering, and erosion strongly affect how local landscapes evolve. Fault damage zones, characterized by intense fracture in the surrounding lithology, form as faults propagate. The Sevier Fault, located in southern-central Utah, consists of six linked fault segments. My research focused on the Spencer Bench segment, in a side canyon to Red Hollow Canyon. This segment displaces the Jurassic Navajo Sandstone. Because the Navajo Sandstone is located on both sides of the fault, any difference in the topography must be caused by damage zone distribution and its resulting impacts on erosional processes rather than by lithologic differences.

We measured fracture orientation and spacing and used an Unmanned Aerial Vehicle to capture imagery of inaccessible outcrops. This imagery was used to construct 3D Structure from Motion models from which I collected further fracture spacing data. We documented fracture characteristics in the footwall and hanging wall and then compared fracture intensity to topography. Due to the headward erosion that this canyon experiences, down-drainage and cross-sectional topography profiles oriented perpendicular to the fault could be constructed to perform Space for Time analyses. The uppermost reaches of the canyon represent the youngest valley profiles, while the southernmost represent the most mature. We compared valley slopes down-drainage within the hanging and footwall to identify any differences. While the slopes do not change significantly across profiles, there are significant differences in the slope and fracture intensity between the hanging and footwall. I hypothesize that the evolution of fault-controlled landscapes is impacted by damage zone development. The observed asymmetry in damage zone distribution results in higher weathering potential on the footwall compared to the hanging wall, as evidenced by the asymmetry in topographic slope. My results shed light on the style of topographic evolution in fault-controlled landscapes, and lead to a broader understanding of the linkage between tectonic stress, strain, and physical landscapes.

Reconstructing Nitrogen Dynamics in Three Minnesotan Lakes Using Stable Isotope Ratios of Nitrogen

Emma Revenaugh

Advisor: Dr. Henry Fricke, Colorado College

As a primary biogenic nutrient, nitrogen is critical to the function of lake ecosystems, and is considered a strong indicator of lake health. In abundance, excess stores of nitrogen, in addition to phosphorus, trigger massive increases in the activity and community size of primary producers (phytoplankton, algae, and macrophytes), which can ultimately result in large-scale dissolved oxygen depletion and decreases in lake biodiversity and water quality. By extension, nitrogen fluxes into lakes–from external landscapes and from internal nitrogen sources–play a major role in lake health.

The primary goal of this study is to characterize the size and external contributions from the surrounding watershed to the N-reservoirs of three Minnesotan lakes (Portage, Barrs, and Pike), as well as to better understand processes of primary productivity, nitrogen cycling and sinking that may be occurring in these lakes. The methodology of this study is modeled after a range of paleolimnological studies using stable isotope ratios to explore N dynamics in lakes, namely Talbot, 2004. For this study, nitrogen isotope ratios were collected from surficial lake sediments using ~30 cm short cores, four cores in total, across three lakes of variable size and surrounding land usage.

Nitrogen sources can be determined based on data collected from coring, since different nitrogenous materials (fertilizers, aquatic and land plants, sewage, etc) have distinct $\delta^{15}N$ signatures. The sources of nitrogen comprising the lake's reservoirs were evaluated two-fold: more simplistically using only $\delta^{15}N$ values, and using a combined $\delta^{15}N$ and TOC/TON graphical analysis, with a framework and material signatures provided in Wu et al., 2021. In this study, we identified $\delta^{15}N$ evidence of agricultural runoff in Portage, terrestrial and aquatic vegetation in Barrs, and algae, soil, and potentially sewage in Pike. All of these observations conform with common land uses adjacent to each lake, reinforcing ideas presented in Soranno et al., 2015 and Lu et al., 2010, that land use within adjacent watersheds is a significant determinant for identifying external nitrogen fluxes.

Processes of primary productivity, nitrogen cycling, and nitrogen sinking are evaluated based on basic statistical analysis of covariation between $\delta^{15}N$ and %N, and significant trends in both across core depth, a method utilized in Talbot, 2004 . The underlying logic of this method, as established in Torres et al., 2012, is to use %N as a proxy for N-reservoir size, to contextualize whether trends in $\delta^{15}N$ are best attributed to decreases or increases in the size of the nitrogen reservoir and primary productivity, and to potentially identify evidence of internal nitrogen cycling or sinking. Trends in %OM are used here to further verify proposed processes of biological utilization. From these analyses, we identified a relationship between high primary productivity/ a large N-reservoir and evidence of internal cycling in Portage Lake, and a relationship between a small N-reservoir and evidence of N cycling in Pike Lake. We also identified higher nutrient densities and strong indicators of high primary productivity and high organic biomass in shallow lakes (Portage and Barrs) compared to deep lakes (Pike). Taken together, nitrogen isotope ratios from surficial lake sediments have the potential to provide valuable information regarding mechanisms driving nutrient density and productivity in lakes, with implications for lake health management.

A Carbon Isotope Investigation of Fossil Leaves from Corral Bluffs

Katya Nicolayevsky
Advisor: Dr. Henry Fricke, Colorado College

The bolide impact at Chicxulub 66.02 Ma resulted in a mass extinction event (the K-Pg event) that included the loss of non-avian dinosaurs and other vertebrates larger than ~ 10 kg in mass, as well as loss of ~57%-75% all plant species. The result was total ecosystem collapse in both marine and terrestrial environments. Until recently, a lack of high-resolution sedimentary records of the earliest Paleogene period (i.e. the Paleocene epoch) have made it difficult to study how terrestrial ecosystems recovered after the K-Pg event, information that has relevance for our present and future. Discovery of a fossil-rich record of the latest Cretaceous and early Paleogene at Corral Bluffs, Colorado has changed this situation, and paleontologists have recently described changes in plant and animal communities taking place over the first 1 Ma of the Paleogene (Lyson et al. 2019). Although the kinds of plants living in the area are now known, the three dimensional structure of resulting forests (that is how close they grew to each other and their relative heights) has not been described.

The goal of this study is to use carbon isotope ratios ($\delta^{13}C$) of plant fossils as a proxy to infer forest structure, and to provide estimates of mean annual precipitation (MAP). Fossil leaf samples well collected from 86 specimens from four sites, one in the Late Cretaceous and three from the first million years of the Paleocene. Carbon isotope ratios indicate that all forests most likely had ‘closed canopy’ structures, meaning they were characterized by variable tree heights and close growth that limited sunlight to the ground and limited moisture loss to the atmosphere. In addition, MAP estimates of over 3 meters/year indicates these were rainforests This amount of rainfall, when paired with forests exhibiting a closed canopy structure, allows us to describe these environments as “rainforests”. The rapid reorganization of forests into a closed canopy after the K-Pg event provides important context for considering the diversification of plants and animals in western North America.

XRD & Raman Spectroscopy of Serpentinite Minerals from Nelson, New Zealand

David Mims, Galileo Defendi-Cho, Tirso Jesus Lara Rivas
Advisor: Dr. Michelle Gevedon, Colorado College

The geological processes of tectonic plate convergence and divergence in the New Zealand area, including those which deposited the Dun Mountain Ophiolite in its current location, are difficult to reconstruct. Identifying the mineral composition of rock samples from across the ophiolite can help us learn about this history, especially in serpentinite-rich sections. Serpentinite forms when ultramafic rocks containing high percentages of olivine and pyroxene are exposed to seawater and hydrated at temperatures ranging from 85-460 degrees C, generally at seafloor spreading centres, or during subduction/abduction. Different polymorphs of serpentinite form at different temperatures and pressures, and thus can be used to deduce past conditions in the areas in which they formed. As these polymorphs can not be visually distinguished in thin sections. Raman spectroscopy was used to distinguish between the serpentinite polymorphs, and XRD and XRF were used to further determine the mineral composition of the ophiolite samples. Throughout the ophiolite, serpentinite grains, veins, and groundmasses across many generations were identified primarily as Lizardite, with a small amount of Chrysotile, and no Antigorite observed. This indicates that the ophiolite predominantly formed at relatively low pressures, with the potential for higher temperatures up to ~300 degrees C. As such, we can determine that the bulk of the Dun Mountain Ophiolite serpentinite was not formed as the oceanic crust was subducted underneath the continental crust, as this would create higher pressure conditions, and instead was serpentinized during seafloor spreading, and/or during the abduction event that brought it to where it is today.

Investigating Tourmaline-Mineralized Mirrored Brittle Faults in Western Antarctica for Seismic Signatures

Annie Breyak
Advisors: Dr. Christine Siddoway, Colorado College

West Antarctica, and the Antarctic continent as a whole, is lacking in geological evidence of seismicity. Exposures of faults are sparse, due to the extensive cover of the continental ice sheet and the tendency of glaciers to localize within the damage zones of faults. Hand samples collected from three study sites, Mt Dolber, Mt. Douglass, and Lewissohn Nunatak, in the southern Ford Ranges in Marie Byrd Land, display mirrored fault surfaces upon tourmaline. Fault mirrors are indicators of ancient seismicity (Evans et al, 2014), forming from the high-temperature conditions produced by frictional heat generated along fault slip zones during earthquakes (Calzolari et al., 2020), resulting in coseismic mineral precipitation. Thin section petrographic analysis revealed strongly aligned tourmaline grains near the principal slip surface, co-parallel with striae on the mirrored surface, consistent with earthquake (EQ) slip. Microstructures suggest top to the SW shear sense. Petrography and EMPA analyses show unzoned tourmaline, with the dravite variety at Lewissohn Nunatak and schorl at the other two sites. The mineral alignment and uniform composition of tourmaline indicate syntectonic growth along fault planes.

Isotropic material surrounding microbreccia observed in open brittle fractures and 'jogs' may be evidence of pseudotachylyte, a glassy material forming at depth by frictional melting caused by EQs; a convincing marker of seismicity. EMPA analysis indicates the isotropic material in the tensile openings is epoxy, distinguished by steep carbon and oxygen peaks. However, abundant ruptured fluid inclusions, ferro-hydroxide alteration products, fluid inclusion trails, sericite, and replacement minerals bordering open fractures containing the isotropic material may suggest that pseudotachylyte once hosted in the fault rock has since devitrified. The presence of fault mirrors and pseudotachylyte veins together provide promising evidence for flash precipitation of tourmaline from fault-hosted fluids, and frictional slip caused by an EQ, presenting a new understanding of Antarctic seismicity and neotectonics. If the seismic slip interpretation of these samples is correct, the occurrence in the southern Ford Ranges will be the first-known in Marie Byrd Land (the major part of West Antarctica). Faults that sustain earthquake damage can provide effective pathways for the migration of fluid and heat from depth to the surface. As the Antarctic ice sheet thins and glacioisostatic adjustment occurs, the fault pathways may allow increased heat flow, contributing to the destabilization of the ice sheet (Reading et al., 2022). This is a matter of contemporary concern in Antarctica and across the world, with it being the largest potential contributor to sea level rise (Burton-Johnson et al., 2020).

Study of Two Clastic Rock Types Sampled from Glacial Erratics in the Ford Ranges of West Antarctica

Harold Oppenheim

Advisor: Dr. Christine Siddoway, Colorado College

The Ford Ranges (FR) of Marie Byrd Land (MBL) were exhumed during Cretaceous extension which led to formation of the West Antarctic Rift System (WARS). The FR are part of a continental scale basin-and-range province which formed during this period and spans much of western MBL. Continental crust has subsided below sea level in the Ross Sea Embayment (Tankersley et al., 2022; Balestrieri et al., 2023). Widespread glaciation conceals sedimentary basins of the FR, but geophysical surveys show that sedimentary deposits fill the topographic lows to depths of over 1km (Siddoway et al., 2018). All evidence points to their existence, but there is not a single exposure of basin-fill sedimentary rock in MBL. Erratics on ridge-top moraines in the FR provide the only view into these local sedimentary provinces. In these moraines, a rare few among mostly granitic erratics are clastic sedimentary rocks.

Two samples included in this study (SC-M1 and SC-A1) provide a window into the subglacial bedrock of the FR and present an opportunity to unlock new information about the nature of MBL's sedimentary basins. This study examines the features of two samples using microscope observations of thin sections to assess the samples' key characteristics which may reveal the depositional settings, along with U-Pb zircon geochronology to determine age. Petrographic work revealed delicate features (i.e. glass, pumice wisps, etc.) in both samples that suggest the samples originated as rhyolite breccias of volcanic origin. Volcanic glasses are highly susceptible to weathering and alteration under surface conditions. The textures may owe their preservation to rapid burial that removed the samples from the effects of weather and groundwater in surface environments. This discovery of siliceous volcanic rocks is consistent with active-rift processes, that at an advanced stage may include caldera eruptions. U-Pb dating promised to situate the volcanic activity in time. For sample SC-M1, few zircons were obtained, so a straightforward determination of date isn't possible. Rounded detrital zircons have widely varied ages that overlap in time with U-Pb age distributions known from local Swanson Formation metagreywacke of early Cambrian age. A sound interpretation is that the sparse zircon is inherited. U-Pb data for SC-A1 yielded a date of 109.2 Ma +/- 2.7 Ma, which was determined from n = 6 concordant igneous grains. Therefore the SC-A1 volcanic breccia formed during WARS extension in the Cretaceous period. SC-A1 extends the known span for pyroclastic activity in the WARS of Marie Byrd Land to ~ 16 million years and potentially reveals the time of onset of felsic eruptive activity in the rift province at ~ 109 Ma. These findings call for the analysis of more clastic erratics from the FR. This study includes a mere two samples, which cannot stand on its own. The sedimentary basins of the FR are largely unresearched, but this study shows that a trove of new information from glacially excavated clasts can offer direction to inform necessary further research.

Using GIS to Reconstruct Colorado's Paleoenvironments

Charlie Hite
Collaborators: Dr. James Hagadorn, Denver Museum of Nature & Science
Dr. Annaka Clement, Denver Museum of Nature & Science
Dr. Holger Petermann, Denver Museum of Nature & Science
Grace King, Colorado College

As a Noblett-Witter intern at the Denver Museum of Nature and Science (DMNS) this past summer I worked for Curator of Geology, James Hagadorn, as well as postdoctoral researchers Annaka Clement and Holger Petermann. I worked on a variety of projects from organizing a recently donated collection of conodonts to doing paleontological fieldwork in North Dakota. However, the project I spent the most time on, and the focus of my poster, was the museum's Paleogeographic Mapping Project which focuses on creating paleoenvironmental maps of Colorado throughout each geologic time period of the past 550 million years. The Earth Sciences Department at the DMNS hope that these maps will provide researchers with accessible, detailed, and highly accurate information on Colorado's paleoenvironments. The project also places great emphasis on sharing our methods and sources, so that scientists from around the world can replicate our paleo-satellite maps for their study areas. My work was the first step of the process—mapping out sedimentary outcrops. I worked with CC Geology class of 2023 graduate, Grace King, using ArcGIS Pro to map relevant geologic formations for the specified time period for Colorado and the surrounding states of the Rocky Mountain Region.

Variations in Crystallographic Preferred Orientation within Different Rock Types in the Talkeetna Arc, AK, and Analog Deformation Experiments

Ilene Kruger

Advisor: Dr. Nadine Grambling, University of Delaware

This project builds on previous studies of olivine deformation and fabric formation through two avenues: analysis of natural mantle peridotite samples from the Talkeetna Arc, Alaska, and experimental deformation of olivine samples on a Griggs-type rig. The overarching goal of the project was to study olivine fabric formation in different conditions - both natural and experimental - paying particular attention to the pressure/temperature transitions between types. We analyzed six natural samples from Mehl et al. (2003): one each of dunite, harzburgite, and websterite from two field sites, Bernard Mountain and Sheep Mountain. In each sample, we identified the lattice preferred orientation (LPO) of naturally deformed olivine grains using an Electron Backscatter Diffraction (EBSD) detector as well as the compositional makeup using an energy-dispersive detector (EDS). This work was conducted under the supervision of Jessica Warren at the University of Delaware. We aimed to discern differences between samples from both sites and rock types, as well as corroborate data and claims made by manual analysis in Mehl et al., 2003. The experimental portion of the project was carried out on a mechanically confined Griggs-type rig at Brown University. We used flow laws in Hirth and Kohlstedt, 2003 to determine the correct proportion of serpentine to hydrate the system based on water fugacity calculations and ran one hydrostatic and one deformation experiment with the goal of refining the conditions necessary for E-type olivine fabric formation. The sample we deformed was 8% Japanese serpentine, 10% >106 um SCO, and 82% 40-70 um SCO. Later FTIR analysis was performed to determine the concentration of water in the sample to compare to the estimation from the olivine flow laws. Analysis of natural samples yielded some discernible differences between the Sheep and Bernard samples, namely that the Sheep Mountain samples are more olivine-rich than the Bernard samples. Additional analysis of the SEM data from natural samples is forthcoming as part of future work, but preliminary results indicate various differences in grain size and hydrothermal alteration throughout the samples.

Constraining the Temporal Onset of Laramide-style Tectonics with Monazite and Apatite U-Pb Geochronology

Jake Hams
Advisors: Dr. Michelle Gevedon, Colorado College
Brody Friesenhahn, Southern Methodist University
Dr. Rita Economos, Southern Methodist University

Constraining the timing of the transition from Mesozoic subduction and arc magmatism to Laramide-style tectonics is important to further understanding the assembly of western North America. Host-rock and dike swarm relationships in Joshua Tree National Park, located within the eastern Transverse Ranges of southern California, provide unique opportunity to constrain the timing of crustal cooling following the end of Late Cretaceous regional arc magmatism leading up to the Laramide orogeny. Here, 1.8 Ga crystalline basement (migmatitic gneiss) of the Mojave crustal province (e.g., Strickland et al., 2013), is intruded by ~88 to 84 Ma and ~76 to 72 Ma granitoid plutons. The 88 to 84 Ma plutons are interpreted as a pulse of Mojave arc-magmatism; the ~76 to 72 Ma plutons are interpreted to record a shearing event and emplacement of granitoid bodies attributed to the onset of Laramide tectonics (Friesenhahn, 2018). Ductile deformation indicates both generations of plutons represent crustal conditions below the brittle-ductile transition. A dike swarm of unknown age hypothesized to represent a brittle deformation regime crosscuts these ductily deformed plutons within Wide and Long Canyons in Joshua Tree National Park. Obtaining emplacement ages of this dike swarm provides opportunity to constrain the timing of the transition from ductile to brittle crustal conditions associated with the transition to Laramide-style tectonics following cessation of arc magmatism.

We propose U-Pb geochronology of monazite and apatite provide the ideal means to determine the age of the dikes. Although zircon U-Pb geochronology is often used to determine ages of igneous bodies, zircon in dikes is generally inherited from their host rocks; due to the refractory nature of zircon, Zr concentrations in dike magmas are typically low, which limits the growth of new autocrystic zircon. The U- Pb system in monazite has closure temperatures similar to zircon, hypothesized to be >800°C (e.g., Cherniak et al., 2004; MacFarlane and Harrison, 2006,) however, saturation in P is readily achieved and promotes the formation of autocrystic monazite from dike magmas. The U-Pb system of apatite is hypothesized to have lower closure temperatures (e.g., 350 to 570°C; e.g., Chew and Spiking, 2021), and may provide a protracted cooling history of the crust following the intrusion of the cross-cutting dike swarm.

Steps to acquiring monazite and apatite U-Pb ages include: (1) elemental mapping of P, Ca, Ce via SEM to find monazite and apatite from heavy mineral separates and in thin section; (2) Measuring U-Pb ratios in apatite using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) at the University of Texas; and (3) Measuring U-Pb ratios in monazite via secondary ion mass spectrometry (SIMS) using the Cameca 1280 large radius ion microprobe at the University of Hawaii.

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