SOUTH DAKOTA MINES
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Department of Geology and Geological Engineering

Recent theses/dissertations: Fall 2019 – Spring 2022

Fall 2019:

NOTICE OF THESIS DEFENSE

MS Candidate: Shannon Harrel

Program: Paleontology

Title: Taphonomic Effect of Fluvial Sediment Abrasion on Dental Microwear

When: Tuesday November 5th, 2019 2:00 PM

Where: Paleontology Research Laboratory – Room 153

Shannon Harrel's research was conducted under the direction of Major Professor Dr. Darrin Pagnac.

Abstract

Dental microwear, microscopic features appearing as pits or scratches on tooth enamel from food abrasion and wear patterns, provides insight into the dietary habit of herbivorous taxa, both extant and extinct. However, taphonomic processes, specifically sediment abrasion during fluvial transport, may alter microwear, imparting an inaccurate signal that can adversely affect identification of specific dietary behavior, thus altering the interpretation of diet. This project assessed the effects of fluvial sediment abrasion on ungulate dental microwear.

The results varied from those previously acquired from hominid teeth, as tooth size, shape and enamel thickness vary among taxa. Results show that sediment abrasion does qualitatively affect microwear signals. Original microwear signals on modern Odocoileus virginianus teeth were either obliterated during simulated taphonomic transport or additional signals were acquired, increasing the number of pits or scratches observed. However, the quantitative results fail to fully reject the null hypothesis, which states that sediment abrasion would have no effect on dental microwear signals. Testing reflects statistical significance in the total number of scratches observed pre versus post taphonomic transport but there was no significant difference observed in the total number of pits acquired post transport.

Although quantitative results are inconclusive, the assumption that qualitative analyses infer dietary behavior may not be entirely accurate. Odocoileus virginianus is an identified browser with microwear signals that include more pits than scratches. However, post taphonomic transport observation reflects more scratches than pits, inferring grazing behavior. This inaccurate signal observed in an extant species of ungulate reflects what may be observed in extinct ungulate microwear signals. Based on previous research and the potential for inaccurately inferred diet, established behaviors applied to extinct taxa based on microwear will need to be revisited.

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NOTICE OF DISSERTATION DEFENSE

PhD Candidate: Kyle Hazelwood

Program: **Geology** and Geological Engineering

Title: Late Cenozoic history of the Black Hills of South Dakota and Wyoming: a study of landscape evolution via stream profile analysis

When: Wednesday November 13th, 2019 9:00 AM

Where: Surbeck Center – Bump Lounge

Kyle Hazelwood's research was conducted under the direction of Major Professor Dr. Larry Stetler.

Abstract

The Black Hills of South Dakota and Wyoming contain perplexing topographic and depositional features that suggest a complex post-uplift history (~30 Ma to present). These features include isolated high-elevation Tertiary sediments lying unconformably on the older tilted bedrock of the uplift and large high-elevation areas with low local relief. A detailed understanding of these features has not been constrained, leaving the recent erosional history of the Black Hills largely unclear.

To provide insight into the history constrained by these features, a comprehensive fluvial analysis of the entire Black Hills stream network and extensive study of Tertiary sedimentary deposits were completed. In order to identify and constrain fluvial incision events, longitudinal profile generation and slope-area regression analysis were completed on the 19 major watersheds draining the central Black Hills. To constrain relationships between deposition and erosion events, a new ArcGIS technique referred to as "watershed decomposition" was developed and documented. This technique allowed the transfer of Tertiary deposits onto corresponding longitudinal profiles throughout the Black Hills. In order to constrain spatial distribution of differing Tertiary sediment age groups, source map data throughout the Black Hills were digitally compiled in ArcGIS and updated based on field study.

Over 295 actively migrating knickzones were identified in stream channels of the Black Hills. These features constrained a relict Oligocene (~30 Ma) fluvial landscape and Pliocene (~3.6 Ma) intermediate fluvial landscape which are extensively preserved in the Black Hills topography. Each of these erosion surfaces are undergoing continuous incision and by streams in response to recent (post ~5 Ma) tectonic uplift events. Two age groups of Tertiary sediments, Oligocene (~30 Ma) and Pliocene (~3.6 Ma), were correlated to the erosional landscapes, both containing evidence for deposition on the fluvial surfaces and post-depositional tectonic deformation. Drainage patterns associated with erosional surfaces were found to predate the formation of the Cheyenne River watershed, which has since captured the Black Hills streams and introduced additional incision related to continental glaciations to the east.

These results concluded that the Black Hills were once (~30 Ma) much more subdued than today and contained a continental drainage divide between the Artic and Atlantic oceans. Driven by two previously undocumented tectonic events, fluvial incision was initiated and has since removed ~2,700 km^3 of material (~6.8 trillion metric tons) from the range, adding ~300 m of associated relief. The characterized erosion surfaces, Tertiary deposits, and incision events are likely linked to widespread formation and subsequent dissection of the former High Plains surface. At present, channel confinement, lack of potential floodwater storage, steepened stream gradients, and active mass wasting events exists in knickzone erosion fronts. Therefore, the results of this work should be considered when studying factors influencing large flood events and landscape stability on the flanks of the Black Hills.

NOTICE OF DISSERTATION DEFENSE

PhD Candidate: Umit Yildiz

Program: **Geology** and Geological Engineering

Title: Characterization of Fault Architecture and Fault Seal Analysis at Cherokee Ridge, Greater Green River Basin, South-Central Wyoming

When: Tuesday November 19th, 2019 8:30 AM

Where: Classroom Building – Room 329

Umit Yildiz's research was conducted under the direction of Major Professor Dr. J. Foster Sawyer (Emeritus Professor, Fall 2021).

Abstract

A fault seal analysis was performed for select faults within the Niobrara Formation at Cherokee Ridge, Greater Green Basin, south central Wyoming. Uncertainties regarding fault behavior in settings such as these present fundamental challenges in understanding fluid flow, compartmentalization, and other reservoir characteristics. The goal of this study was to determine whether the faults act as barriers or conduits to fluid migration and whether they have a profound effect on fluid flow and compartmentalization within the reservoir. To address this issue, a 3D pillar grid geologic model was created to perform a fault seal analysis utilizing 3D seismic and sparse geophysical well log data.

The Niobrara Formation ranges in thickness from 1,200 to 1,560 ft (365 to 475 m) with a 5,500 ft (1,676 m) structural relief in the study area and consists mainly of interbedded organic rich shale (65%), carbonates (26%), and silt (marl) (9%) lithofacies. Results of the modeling in this study indicate that Vcl values range from 15% to 62%, porosity values range from 4% to 23%, and permeability values range from 0.02 mD to 2.08 mD for the Niobrara Formation.

Major fault interpretations within the study area show that there is a distinct fault strike direction of east-west. The faults are generally high angle in nature with dips ranging between 70° and 82°, and fault plane dip directions vary between northward and southward. Horizontal lengths for the faults that were selected for the study range from0.86 to 5.8 mi (1.4 to 9.3 km) in length. CR1, CR2 and CR5 are dip slip faults with no visible lateral motion,

whereas CR3 and CR4 indicate oblique sense of motions, right separation, and left separation respectively.

The fault seal analysis was successfully completed, and a workflow was established as follows: First, major faults and tops and bases for the Mancos Shale, the Niobrara Formation, and the Frontier Formation were interpreted from seismic and well log data, second, facies and petrophysical properties were modeled, and third, 1D and 3D juxtaposition analyses were conducted. Finally, fault clay content, effective fault rock permeability, and transmissibility multipliers were predicted. Fault clay content was predicted as more than 20% for the major faults which suggests the faults are sealing.

Transmissibility multipliers (TM) calculations also indicate that the TM values for the major faults within the study area range from a minimum of 0 to a maximum of 0.92 which further indicates the major faults are prone to seal. An amplitude variation with offset (AVO) analysis shows anomalous bright spots that may be interpreted as the occurrence of possible compartmentalization within the Niobrara Formation. These findings may provide significant insight into future exploration and field development strategies.

This research also provides clear evidence that a fault seal analysis can be successfully performed by interpreting 3D seismic and sparse well log data in an underexplored basin. The established workflow provided during this study includes the critical steps of structural interpretation, property modeling, and fault seal analysis that can be used as a road map for future scientific and industrial investigations.

NOTICE OF THESIS DEFENSE

MS Candidate: Caleb Ubl

Program: Geology and **Geological Engineering**

Title: Statistical Analysis of Interpolation Methods for Determining Aquifer Elevations Using ArcGIS

When: Friday November 22nd, 2019 12:00 P.M.

Where: McKeel Room – Surbeck Center

Caleb Ubl's research was conducted under the direction of Major Professor Dr. Larry Stetler.

Abstract

Statistical analyses of aquifer surface interpolation methods were investigated for the High Plains aquifer. The study was driven by increased withdrawal of groundwater and the expectation for future increases. The High Plains aquifer consisted of the Arikaree, Ogallala and Sand Hills aquifers and thickness of each was extracted using well logs and imported into a groundwater model. Aquifer thicknesses were interpolated using a total of 9 methods and 20 intermethods that yielded 162 separate surface interpolations. The most statistically valid models for the Arikaree, Ogallala and Sand Hills aquifers were a variant of Simple Kriging, Natural Neighbor, and a

variant of Ordinary Kriging, respectively. These interpolations generated basal elevation rasters for their respective aquifers and thicknesses of these aquifer were generated. The statistical analysis showed that the most viable general options for creating elevation surfaces was Topo to Raster and Natural Neighbor interpolations. These analyses will provide hydrologists a statistical routine to construct and compare interpolation models.

NOTICE OF THESIS DEFENSE

M.S. Candidate: Benjamin Zalneraitis

Program: Paleontology

Topic: Determining Risk of Fossil Loss Using Close-Range Photogrammetry in the Sharon Springs Formation of the Pierre Shale Group

When: Thursday, November 21, 2019 – 1:00 P.M.

Where: Surbeck Center – Bump Lounge

Benjamins Zalneraitis's research was conducted under the direction of Major Professor Dr. Maribeth Price.

Abstract

This study was designed to determine a mathematical relationship between rainfall and erosion in the Pierre Shale Group of western South Dakota. Plot-scale measurements of erosion were made using an erosion bridge and close-range photogrammetry, and these measurements were compared to the movement of artificially placed fossil specimens. The site was located on the Brown Ranch between Hermosa and Rapid City, South Dakota, and contains numerous large hillside exposures of the Pierre Shale Group, which have been known to be fossil-bearing.

Erosion was tracked using close-range photogrammetry on the scale of a plot, using a measurement device called an erosion bridge to measure the ground surface and estimate the erosion manually. The photogrammetric images were used to create three-dimensional models, which were intended to be converted to digital elevation models for the purpose of digitally calculating the total volume loss. This loss was to be compared to the rainfall data for the study area in order to develop a relationship between the magnitude of rainfall and the magnitude of erosion. Excursions were made to the study area after major rainfall events to make these measurements.

Fossil specimens with no practical scientific value were selected, lacking all identifiable features placing them any better than familial designation. These fossils were placed and marked over the study area and were tracked as they moved. The tracking took place on the same trips as erosion measurements were taken. The movement of these fossils was compared independently to the rainfall and erosion to determine which had a stronger influence on the movement of the fossils.

The small number of data points hampered the use of statistical comparisons to determine the strongest influence on fossil movement, as did disturbance of the plots by cattle. However, qualitative observations of the outcrops indicated that rainfall was a stronger control

on fossil movement than overall erosion. The erosion observed in the plots was inconsistent, with variable amounts of sediment accrual or erosion even on the scale of a single plot. Large rainfall events did not consistently result in either loss or gain of sediment. Fossil movement did tend to occur in times of erosion but was not closely tied to rainfall events.

The strongest relationship between the movement of fossils on the shale was their proximity to recent drainage channels. Fossils near the drainage channels had the highest chance of being exhumed, moved, or even reburied, whereas fossils placed even a few meters from active drainage channels showed little to no movement outside of interference from cattle. Once exhumed, continued proximity to the channel placed the specimens at high risk for disturbance or reburial by subsequent rainfall events.

Spring 2020:

Notice of Thesis Defense

MS Candidate: Imren Yilmazgoz

Program: **Geology** and Geological Engineering

Title: Petrographic and Mineralogic Characterizations of Gold Mineralization with the Rochford Formation, Rochford District, Black Hills, South Dakota

When: Thursday April 2nd, 2020 9:00 AM

Where: Zoom video conference

Imren Yilmazgoz's research was conducted under the direction of Major Professor Dr. Nuri Uzunlar.

Abstract

The Rochford District is situated in the northern part of the Black Hills, South Dakota, and approximately 20 miles (32 km) south of the Homestake Mine, which is one of the world's most important and famous banded iron formations (BIFs) hosted gold deposits. Gold mineralization at the Homestake Mine is known to be closely linked to a complex Proterozoic deformation and metamorphic history that has affected the entire Black Hills region. All studies done so far in the Rochford District show that host rock composition, structural style, metamorphic grade, mineral and alteration assemblage, and deformational history of these two districts are very similar. The economic value and geologic importance of the Rochford District have been the focus of new interest in the last decade due to its geologic similarities and proximity to the Homestake Mine. These similarities and their proximity suggest that the Rochford District may have the potential to contain a world-class orogenic gold deposit like the Homestake Mine. Despite the geological similarities and proximity between these two districts, there has been no detailed study of the gold mineralization in the Rochford District. The recent prospecting has identified that the Rochford District has anomalous gold values, including some samples exceeding 10 ppm Au (Mineral Mountain Resources, unpublished data).

The drilling program conducted by Mineral Mountain Resources in the Rochford District provided core samples of eight drill holes, and gold and arsenic assay values of the core samples. The present study focusses on the mineralogical, petrographical, geochemical, statistical, and paragenetic studies to examine the gold mineralization of the Rochford District utilizing drill hole data, petrographic thin sections, trace element geochemistry of the core samples. The objectives of this research are to characterize gold mineralization, determine mineral paragenesis and different stages of sulfide and gold mineralization, and define possible pathfinder elements associated with gold mineralization.

Gold mineralization in the Rochford District is hosted by greenschist to amphibolite facies metasedimentary rocks mainly within the Rochford Formation. Ore-grade Rochford Formation is sulfide-rich, dominated by pyrrhotite, arsenopyrite, and minor pyrite and native gold. Petrographic characterization of 22 samples from the Rochford Formation has defined a close textural association of gold and arsenopyrite, which implies that arsenic is the most effective pathfinder element for regional gold exploration. The mineralization sequence of sulfides is characterized by two generations of pyrrhotite as Po1 and Po2, and two generations of arsenopyrite as Aspy1 and Aspy2 in addition to the presence of inclusions of minor amounts of chalcopyrite and pyrite. Based on paragenetic relationships, three main mineralization stages are recognized in the studied part of the drill cores. Gold is most related to the third stage, or as a transition between all of them. All microscopically visible gold occurs as inclusions within sulfide (mainly in arsenopyrite), or as fracture filling, less commonly free grains occur in the metamorphic matrix. Grain sizes of gold range from 5 to 40 μm in granular sheet shapes.

Notice of Thesis Defense

M.S. Candidate: Todd Anderson

Program: Geology and **Geological Engineering**

Topic: Groundwater-flow Model and Simulation of Dewatering Scenarios of Alluvial Deposits, Northern Summerset, South Dakota

When: Friday April 17th, 2020- 3:00 P.M.

Where: Zoom video conference

Todd Anderson's research was conducted under the direction of Major Professor Dr. Liangping Li.

Abstract

A groundwater model was constructed and simulated using MODFLOW–6 to evaluate the groundwater conditions of an alluvial aquifer near the Sun Valley Estates Development of Summerset, South Dakota, after groundwater flooding damaged basements of housing in the summer of 2019. The model was calibrated using PEST++ to match observed and simulated heads. The optimal hydraulic conductivity for the modeled alluvial aquifer determined from model calibration was 0.24 ft/day, and the optimal specific yield was 0.02. Water budgets of the model suggest that the alluvial aquifer is highly connected with the underlying geologic units. A dewatering scenario using two pumping wells with 100 gallon per minute pumps was simulated

and demonstrated the capability of dewatering the area of flooded houses in the development. More data needs to be gathered to add confidence to the model and reduce uncertainty.

Notice of Thesis Defense

MS Candidate: Taran W. Bradley

Program: **Geology** and Geological Engineering

Title: Pressure and Bulk Composition Effects on Near Infrared Spectra of White Micas in High P/T Metamorphic Terranes: A Case Study in Northwest Turkey

When: Thursday April 16th, 2020 1:00 P.M.

Where: Zoom video conference

Taran W. Bradley's research was conducted under the direction of Major Professor Dr. Gokce Ustunisik.

Abstract

Samples formed at similar temperatures but under a range of pressure conditions and bulk compositions from northwestern Turkey were analyzed with Vis/NIR spectroscopy and electron probe microanalysis (EPMA). Results show a strong correlation between Al-OH absorption band wavelength and white mica composition (i.e., aluminoceladonite exchange) in samples from three distinct metamorphic terranes. Comparing two regions with reported metamorphic temperatures near 450°C, the wavelength of the Al-OH absorption band in lower blueschist facies samples with reported pressure of 11 ± 2 kbar is 2222 nm and in transitional eclogite facies samples with pressure of 24 ± 3 kbar the wavelength is 2232 nm. This is consistent with an increase in Al-Cel component, measured by Si content, from 3.32 a.p.f.u in the lower pressure sample(s) to 3.58 a.p.f.u in the higher-pressure sample(s). However, there is no visible difference in the Al-OH absorption band between a calc-schist and blueschist formed under similar P/T conditions. Thus, a correlation between bulk composition and Al-OH absorption band wavelength is not present. Results show that Vis/NIR spectroscopy can provide semi-quantitative information regarding the P/T conditions in collisional tectonic settings while in the field.

Notice of Thesis Defense

MS Candidate: Kristen Lewis

Program: **Geology** and Geological Engineering

Title: Experimental Constraints on Homogenization of Plagioclase-Hosted Melt Inclusions from Plagioclase Ultraphyric Basalts

When: Tuesday April 14th, 2020 11:00 A.M.

Where: Zoom video conference

Kristen Lewis's research was conducted under the direction of Major Professor Dr. Gokce Ustunisik.

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Abstract

Melt Inclusions (MIs) are a means of determining the melt composition at the time of entrapment in the crystal host. Often, post-entrapment processes modify the entrapment composition. Here we present a series of low- and high-pressure homogenization experiments on plagioclase from Plagioclase Ultraphyric Basalts of the Juan de Fuca Ridge and Blanco Fracture Zone designed to develop a methodology for recovering the composition of plagioclase hosted MIs that represents the magma at the time of entrapment. Our goal is to evaluate the magnitude of changing parameters including pressure and time used during homogenization. To do this, low pressure (1 bar) homogenization experiments were conducted as a time series (30 min, 4 hrs, 1 day, 4 days, and 8 days), while high pressure (7.5 kbars) homogenization runs were completed at 2 and 4 days. Compared to low pressure experiments run at short run times, 30 min, 4 hrs, 1 day, experiments run at low pressure and run times of 4 and 8 days exhibited compositional drift, most notable in the form of increasing MgO in MIs. This drift is found in both the Juan de Fuca and Blanco Fracture Zone samples. This drift was not observed at 7.5 kbars. It is concluded that the drift in composition with time is driven by crystal relaxation driven by the high internal pressure within the MI (the pressure at which the MI formed), together with the lower confining pressure during homogenization (1 bar). Our experiments showed that constraints including homogenization time and pressure need to be cautioned as we try to remove post-entrapment effects and therefore to correctly evaluate the information presented by MIs.

Notice of Thesis Defense

MS Candidate: Ahmet Yilmazgoz

Program: **Geology** and Geological Engineering

Title: Structural Control on Gold Mineralization in Rochford Formation, Rochford District, Black Hills, South Dakota

When: Thursday April 16th, 2020

Where: Zoom video conference

Ahmet Yilmazgoz's research was conducted under the guidance of Major Professor Dr. Nuri Uzunlar.

Abstract

The Rochford district, which is located approximately 20 miles south of the Homestake Mine, a world-famous iron formation-hosted orogenic gold deposit, is situated in the northern Black Hills. The gold mineralization at Homestake Mine is structurally controlled and is related to the complex deformational and metamorphic history of Proterozoic that is believed to affect the entire Black Hills region. The Rochford district has a large geologic potential for gold mineralization because it shares abundant structural, mineralogical, and metamorphic similarities with the Homestake Mine district. The close similarities between the Rochford district and Homestake Mine make Rochford an important target for gold exploration. This study aims to identify and characterize the structural controls on the occurrence of gold mineralization.

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In order to determine whether the gold mineralization in the Rochford district is a Homestake-type gold mineralization, geologic field examinations, detailed logging of the core samples, gold and arsenic assay data, and the petrographic examination of thin sections were utilized. Core samples and gold and arsenic assay data used for this research are provided by Mineral Mountain Resources (MMR).

The study area consists of multiple plunging fold structures that include three antiforms and three synforms and shear zones that crosscut these folds. The main fold structure is interpreted as the result of fold interference between the folding event F1 and F2. The F2 folds refolded F1 folds; thus, the thickened F2 fold hinges thicken the Rochford Formation even further. The heterogeneous strain associated with these events has triggered local shearing, resulting in open spaces where free-fluid phases may infill during mineralization. D3 deformational event refolded F2 and produced localized rotations of S2, thus heterogeneously formed S3. Gold mineralization at the Rochford district is synchronous with the D3 event. S3 cleavage and shearing created pathways for gold-bearing fluids, and the gold precipitated in open space within the F2 folds. Gold mineralization in the study area occurs within highly deformed, quartz-flooded, sulfide-rich iron formation, and gold has a strong correlation with arsenopyrite, which can be the best indicator for gold mineralization. The characteristics of the gold mineralization including highly deformed host rock, brittle to ductile type of deformation zones transferring hot gold-bearing fluids from deeper levels, abundant quartz-carbonate veins, and carbonate-sulfide-sericite-chlorite alteration assemblages may refer that gold mineralization at the Rochford is related to an orogenic process and it may be categorized as “orogenic gold deposit.” Evidence derived from this study may suggest that the gold mineralization style of the Rochford district resembles the gold mineralization at Homestake Mine. Future work should focus on developing the structural understanding of deep-seated shear zones, F2 folds at depth, and their intersections. In addition to applying the current understanding of mineralization at the Rochford district, additional drilling and geophysical and geochemical analysis need to implement to help identify new favorable mineralized zones.

Notice of Thesis Defense

MS Candidate: Disha Gupta

Program: **Geology** and Geological Engineering

Title: Assessment of tight oil in the Pierre Shale of South Dakota

When: Thursday April 16th, 2020 - 3:00 PM

Where: Zoom video conference

Disha Gupta’s research was conducted under the direction of Major Professor Dr. Kurt Katzenstein.

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Abstract

The Upper Cretaceous Pierre Shale occurs in South Dakota, Montana, Colorado, Minnesota, New Mexico, Wyoming, and Nebraska in the United States. The Pierre consists of up to 600 m (2000 ft) of dark gray shale, sandstone, and layers of bentonite. The goal of the study was to assess the existence and possible maturation of tight oil in the Pierre Shale of South Dakota. Tight oil is light crude oil contained in petroleum-bearing formations of low permeability. The focus of the study was two-fold. The first objective was to assess existing pyrolysis data for the Pierre Shale in South Dakota and correlate it with the results of vitrinite reflectance in order to determine if the source rock analyzer is underestimating the values of Tmax. The second objective was to determine if the oil in the Pierre could be self-sourced by looking at its organic carbon content, kerogen type and thermal maturity and if not, then attempt to determine from where it originated. The approach of this study was to determine the organic matter concentrations in the Pierre Shale, classify kerogen type, and determine the thermal maturity. The methods used included pyrolysis by source rock analysis and thermal maturity assessed with vitrinite reflectance.

The study utilized the samples from a core drilled near Presho, SD in 2014-15 and from outcrops along the Missouri River and southern Black Hills in South Dakota. Pyrolysis using Rock Eval on samples from the Presho area suggest that the Pierre Shale at this location has optimum carbon content for the generation of petroleum. It also has the appropriate kerogen type. Also, during the Presho core drilling, oil was found in drilling fluid returns from the lower part of Pierre Shale whereas no oil was returned from the underlying Niobrara Formation. This suggests that the oil is self-sourced. Rock Eval data do not suggest the thermal maturity of the Pierre to be in the oil window, which makes the source of oil a mystery.

Previous literature indicated the Pierre Shale has sufficient organic matter and suitable kerogen types for the generation of oil. The Niobrara Formation below it produces only gas and does not normally contain oil in South Dakota. Thus, it was expected that there was some error in the source rock analysis results and the oil found in the Pierre Shale was self-sourced. This research suggested that there is a possibility that the Pierre Shale might produce oil in some of the areas of its occurrence.

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Summer 2020:

Notice of Thesis Defense

MS Candidate: Jared Long-Fox

Program: **Geology** and Geological Engineering

Title: Integrating Interdisciplinary Data for Analyses of Volcano Deformation: Application to Okmok Volcano, Alaska

When: Monday July 6th, 2020 - 2:00 PM

Where: Zoom video conference

Jared's research was conducted under the direction of Major Professor Dr. Timothy Masterlark.

Abstract

The eruption cycle of a volcano is controlled by the migration and storage of magma. The specific characteristics of the magma migration and spatial distribution of material properties produce a specific deformation signature on the Earth's surface. Inverse analyses of geodetic data are used to optimize controlling geometric and mechanical parameters of the volcanic system. This study uses interferometric synthetic aperture radar (InSAR) data from a 1997 co- and post-eruptive interval for Okmok volcano, located on the northern lobe of Umnak Island in the Aleutian Arc of Alaska, to estimate the location of the magma reservoir and optimize viscosities of a thermally-weakened viscoelastic rind surrounding the reservoir beneath Okmok using finite element models (FEMs). Following optimization of these parameters, approximately 10 years of pre-and post-eruption InSAR data are analyzed to construct a magma reservoir pressurization history using both purely elastic and coupled elastic-viscoelastic models. The findings presented here offer insight into how the rheologic structure of shallow magmatic systems can influence predictions of transient deformation and estimates of available magma budget.

Fall 2020:

Notice of Thesis Defense

MS Candidate: Michael Day

Program: **Geology** and Geological Engineering

Title: Near Infrared Spectroscopy of White Mica and Implications for Metamorphism in the Black Hills, South Dakota

When: Monday November 16th, 2020 - 2:00 PM

Where: Zoom video conference

Michaels's research was conducted under the direction of Major Professor Dr. Edward Duke.

Abstract

Field-based visible and near-infrared spectroscopy is investigated as a rapid and economical method to map regional variations in metamorphic intensity. The study area includes the biotite, garnet, and lower staurolite zones in the Precambrian core of the northern Black Hills, South Dakota. Spectroscopic analysis focuses on the wavelength of the Al-OH absorption feature in white mica that occurs near 2200 nm. Previous studies have shown that the wavelength of the Al-OH feature exhibits a linear increase with progress of the aluminoceladonite exchange in white mica [$^{VI}Al^{3+} + {}^{IV}Al^{3+} = {}^{VI}(Fe, Mg)^{2+} + {}^{IV}Si^{4+}$]; increased Al content corresponds to shorter Al-OH wavelength. In addition, petrologic literature holds that white mica Al content increases with increasing metamorphic grade in settings such as the Black Hills where metamorphism occurred along medium *P/T* gradients. This study includes 1952 field spectral measurements along with thin section analysis of 45 samples to document mineral assemblage and white mica chemical composition. Samples include lithologies with high bulk rock Al content (pelites) and those with low bulk rock Al content (greywacke, quartzite) to address possible effects of bulk composition on white mica composition and Al-OH wavelength. Al-OH wavelength values, mica compositions, and mineral assemblage data are compiled in a geodatabase that includes previously mapped lithologic units, structural features, mineralized districts, and metamorphic isograds. Results show that the wavelength of the Al-OH band shifts from 2218 nm in the biotite zone to 2196 nm in the lower staurolite zone, representing a decrease in Al-OH wavelength with increasing metamorphic grade. Corresponding white mica compositions increase in Al and decrease in Mg, Fe, and Si with decreasing Al-OH wavelength, consistent with the aluminoceladonite exchange. Decreasing $^{VI}(Fe, Mg)$ and shorter Al-OH wavelength is also correlated with an increase in Na/(K+Na) in white mica; this effect is tied to crystal chemical interaction involving the octahedral and interlayer sites and is not directly attributable to metamorphic reactions. Geospatial analysis and empirical Bayesian kriging shows that the spatial variation of Al-OH wavelength values follows previously established metamorphic patterns (e.g., isograds) in most of the study area. However, there are three notable areas where Al-OH values are anomalous with respect to the expected metamorphic pattern. Significant low-wavelength anomalies, implying locally higher-grade metamorphism, occur northwest of Rochford, southeast of Nemo, and along a north-northwest trend west of the Thompson Draw synform in the southwestern part of the study area. In addition, local variations in Al-OH wavelength between adjacent rock units that were presumably metamorphosed at the same conditions may exceed 5 nm; these appear to reflect local variations in lithology, but a clear correlation with bulk rock Al content is not evident. This study demonstrates the potential of using white mica spectroscopy to map patterns of metamorphic intensity. Additionally, this study illuminates potential future studies to understand the compositional effects on Al-OH wavelength and refine the understanding of the metamorphic patterns of the Black Hills.

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Spring 2021:

Notice of Dissertation Defense

PhD Candidate: Lilly Jones

Program: **Geology** and Geological Engineering

Title: Assessing Aquifer Vulnerability to Contamination on the Pine Ridge Indian Reservation in southwestern South Dakota

When: Thursday March 18th, 2021 - 8:00 AM

Where: Zoom video conference

Lilly's research was conducted under the direction of Major Professor Dr J. Foster Sawyer (Emeritus Professor, Fall 2021).

Abstract

Groundwater vulnerability assessment is an essential tool used to guide water resource decisions and contributes to the success of water management programs. Providing accurate models to water resource managers can improve their ability to make scientifically justified decisions. This project consists of an aquifer vulnerability assessment for a series of heterogeneous, unconfined, anisotropic aquifer units on the Pine Ridge Indian Reservation and is intended to provide a baseline aquifer vulnerability assessment to identify locations with the highest potential risk for aquifer contamination. An ensemble modeling approach, based on the DRASTIC (Aller and others, 1985) method, was implemented using analyst-estimated ratings combined with geostatistical methods to illuminate relationships between the seven standard DRASTIC parameters: depth to the water table, recharge rate, aquifer media, soil media, topography, impact of the vadose zone, and hydraulic conductivity. An eighth parameter, land use, was added to simulate anthropogenic influences.

The first challenge for this project was to build a functional geodatabase that could serve both as a repository for data related to this project, designed to function within the current data and infrastructure restraints of tribal entities. The second challenge was to complete a reasonable aquifer vulnerability assessment with the aim of exploring and minimizing uncertainty. Other challenges include the complex nature of the aquifer units under investigation as well as the decentralized nature of water resource management on the reservation as well as a lack of previous studies on this topic in the study area.

The ensemble model predicts that 37% of the study area has a low intrinsic vulnerability to contamination, 42% was rated at a moderate level of intrinsic vulnerability to contamination, and 21% area was rated as having high intrinsic vulnerability to contamination. Fuzzy methods were employed to assess the certainty of these classes with the result that cells classified as having high intrinsic vulnerability are 90% certain. Low ratings demonstrate somewhat greater uncertainty, with 80% of cells in the ensemble model calculated as certain. Geographically, the most sensitive locations in the study area include the Sand Hills area in the southeastern part of the reservation, much of the alluvial aquifer along the White River, and portions of the White River Badlands in the northwestern corner of the reservation. The ensemble model compared well against an existing dataset of arsenic measurements in reservation wells and against a

predictive model for nitrate. Sensitivity analysis was also completed. The most sensitive models in the ensemble stack are the USGS DRASTIC 2014 model and the 2018 standard DRASTIC model. The least sensitive model was the DRASTIC 2018 agricultural model. A discussion of uncertainty in environmental modeling and recommendations for resource management and further study were completed for this project. This project highlights the urgent need to collect and manage data on the Pine Ridge Indian Reservation so that the natural resource needs of tribal communities can be addressed and protected.

Notice of Thesis Defense

MS Candidate: Grace DeVault

Program: Paleontology

Title: Using fossil bone geochemistry and age reports to reconstruct diagenesis at the Pig Dig Site, Badlands National Park, SD

When: Wednesday April 7th, 2021 1:00 PM

Where: Zoom video conference

Grace's research was conducted under the guidance of Major Professor Dr. Sarah Keenan.

Abstract

The Conata Picnic Ground Site of Badlands National Park (V9310) (Pig Dig) was a prolific Orellan assemblage (33.8-32.4 Mya) excavated between 1993 and 2008. The site has been interpreted as a watering hole deposit, consisting of a fossiliferous green mudstone surrounded by red mudstone layers. Measures of individual animal ages (age reports), using comparative tooth wear analysis, have been conducted on the Archaeotherium and Subhyracodon specimens from the Pig Dig, but not the Leptomeryx, Mesohippus, or Hoplophoneus specimens, which also have a minimum number of individuals (MNI) greater than one. This study sought to use age reports from these five taxa, as well as X-ray fluorescence (XRF) results, to determine the geochemical impact of the decomposition of this organic matter on the Pig Dig Site. The age reports for Leptomeryx and Mesohippus were completed, also using relative tooth wear analysis, although the Hoplophoneus age report could not be completed due to a missing specimen. The four analyzed taxa were then subdivided into three mass bins, representing sub-full-grown mass, full-grown mass, and old-aged mass. Using pre-existing mass estimates for taxa, the total masses of organic matter (i.e., carcasses) for each bin, taxon, and in total were calculated. These masses were in turn used to infer the release of carbon (C), nitrogen (N), and iron (Fe), resulting from the decomposition of that mass.

XRF analyses were also completed on fossil and rock samples from the Pig Dig Site. The results from the XRF analyses were evaluated through a series of principal components analyses(PCAs) and Kruskal-Wallis tests. The Kruskal-Wallis tests revealed significant enrichment of magnesium (Mg), aluminum (Al), silicon (Si), and Fe in the fossil bone and teeth compared to modern bone and teeth. The Kruskal-Wallis tests did not return any significant differences between any of the taxa, or between the large (Archaeotherium and Subhyracodon) and small(Leptomeryx and Mesohippus) taxa, using major element chemistry. However, there

were some significant differences in trace element concentrations between the large and small taxa. Statistical analyses also revealed that the rock samples were enriched in Fe, while the fossil samples were enriched in calcium (Ca) and phosphorus (P). The PCAs and Kruskal-Wallis tests also showed that the red layers of the Pig Dig were significantly enriched in Si, Fe, Mg, and Al when compared to the green layers of the Pig Dig.

The mass estimate nutrient release analyses revealed that Archaeotherium contributed the most mass and nutrients to the locality upon decomposition, and Leptomeryx contributed the least. However, as these results are not reflected in the geochemical and statistical analyses, it is evident that further work is needed to understand the impacts of decomposition on locality geochemistry and elemental uptake during fossilization, at this locality and in general. This study also supports prior interpretations of the site as a watering hole and expands our understanding of the role of decomposition on changing site geochemistry and fossil diagenesis

Notice of Thesis Defense

MS Candidate: Gavin Davidson

Program: Paleontology

Title: A Taxonomic Review and Chronologic Correlation of the Fossil Assemblage from the Mission Pit Locality (Clarendonian), South Dakota

When: Wednesday April 7th, 2021 3:00 PM

Where: Zoom video conference

Gavin's research was conducted under the guidance of Major Professor Dr. Darrin Pagnac.

Abstract

The Mission Pit local fauna is a taxonomically diverse Clarendonian fossil assemblage from Mellette County South Dakota that needed a full taxonomic revision and temporal correlation. Twelve mammalian families are represented, namely members of the Equidae, Canidae, Camelidae, Rhinocerotidae, and Amphicyonidae. This assemblage is particularly notable for its abundance of isolated equid cheek teeth. These teeth, and other isolated specimens from a variety of mammalian taxa, were identified using contemporary taxonomic diagnoses. Morphological analysis of taxa present and comparison to other Clarendonian-aged faunas from the Great Plains strongly suggest that the Mission Pit local fauna was accumulated in the second phase of the ClarendonianNALMA, (Cl2). Lines of evidence for this temporal placement include derived dental morphology of the amphicyonid Ischyrocyon gidleyi and the presence of the hipparionineequids Pseudhipparion gratum and Neohipparion affine as well as the borophagine canidAelurodon taxoides. When compared to other Great Plains fossils assemblages the Mission Pit fauna compares most favorably using a cluster analysis in PAST software to the Minnechaduza fauna of Nebraska (Cl2).

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Notice of Thesis Defense

MS Candidate: Jichao Bao

Program: Geology and **Geological Engineering**

Title: Leveraging Deep Learning for Flow and Transport Data Assimilation in Complex Aquifers

When: Thursday April 8th, 2021 2:00 PM

Where: Zoom video conference

Jichao's research was conducted under the guidance of Major Professor Dr. Liangping Li.

Abstract

Groundwater modeling is important for water resources management and aquifer remediation. However, the strong heterogeneity of subsurface and scarcity of observed data are challenging for modeling. Data Assimilation (DA) provides a way to integrate dynamic data such as hydraulic head and concentration data into models, and then optimize initial conditions and model parameters. Moreover, the model predictive ability can be greatly improved, and uncertainty can be significantly reduced with DA approaches. Ensemble Smoother with Multiple Data Assimilation (ES-MDA) has gained popularity for DA in the field of hydrogeology, where aquifer parameters such as hydraulic conductivity are calibrated by conditioning on observed dynamic data. The ES-MDA has an optimal solution if aquifer parameters follow a multi-Gaussian distribution. However, fluvial deposits commonly exhibit a strong heterogeneity with channels (i.e., connectivity). In other words, the hydraulic conductivity does not follow the multi-Gaussian distribution. The impressive performance of Deep Learning (DL) in many fields has shown its ability to handle multi-scale heterogeneous information, which provides a solution to address non-Gaussian conditions. In order to deal with DA in channelized aquifers, ES-MDA is coupled with DL. Specifically, Variational Autoencoder (VAE) and Generative Adversarial Network (GAN), two of the most popular deep learning models, are used to re-parameterize the channelized aquifer with low-dimensional latent variables. The ES-MDA is then used to update the latent variables by assimilating dynamic data into the groundwater model. Synthetic studies of groundwater flow and contaminant transport models are used to demonstrate the performance of coupling ES-MDA with DL. The results illustrate that the coupling of ES-MDA with VAE or GAN is able to reconstruct the channel structures and reduce the uncertainty of hydraulic head and contaminant concentration predictions. Additionally, several examples are presented to compare the performance of VAE and GAN in DA problems. The results demonstrate that GAN can generate much clearer images with less observed data. However, VAE can better reconstruct the channel structures, which is important for predicting flow and contaminant transport.

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Notice of Dissertation Defense

PhD Candidate: Jennifer Bednar

Program: **Geology** and Geological Engineering

Title: Current Limitations, Variability, and Role of Topography in Stream Base Flow in the Northern Great Plains of the United States

When: Tuesday April 13th, 2021 11:00 AM

Where: Zoom video conference

Jennifer's research was conducted under the guidance of Major Professor Dr. J. Foster Sawyer (Emeritus Professor, Fall 2021).

Abstract

Accurately being able to determine stream base flow is critical for a variety of reasons. These include understanding water use including permitting and for other regulatory needs, water quality which can impact ecosystems and habitats, groundwater, and surface water modeling, and understanding anthropogenic impacts to hydrologic systems to include land use changes, irrigation, and diversions. There is a knowledge gap in previous research regarding base flow and temporal variability and physical controls in the Northern Great Plains. This research was performed to better understand the temporal variability and physical controls of stream base flow, along with identifying variations between the humid and semi-arid regions of the Northern Great Plains and finding any local or regional similarities.

The objectives of the study included using existing hydrograph separation methods on sites within the study area to evaluate the seasonal and long-term, or decadal, variations in base flow and the base flow index. The base flow index is the ratio of base flow to stream flow and is used to more easily compare sites. The base flow was estimated at sites with the most available data with the highest confidence based on a set of parameters that were applied to each site. Parameters were based mostly on current limitations of base flow estimation and included drainage areas >1 square mile, <5,000 square miles, minimal anthropogenic affects (e.g., diversions, irrigation), perennial stream systems, and complete data with a period of longer than 40 years. The base flow estimates and base flow indices were graphed over the periods of 1980-1989, 1990-1999, 2000-2009, and 2010-2019 and 10-, 20-, 30-, and 40-year averages. Spearman's rho was used to correlate physical controls (topographical) to the base flow and base flow indices. Stream sinuosity, average basin slope, average basin elevation, and drainage size were also analyzed.

Across the study area the highest amounts of base flow were in the spring months, with the lowest being in the winter. The base flow index was the inverse of this with the highest base flow indices in the winter months and the lowest in the spring months. Seasonal variability in base flow showed that there were regional similarities in the trends of base flow and base flow indices. Long-term base flow estimates showed that after a period of 20 years the base flow and base flow indices rarely changed, meaning the values were very similar whether the entire period of record was used (e.g., 80 years) or 20 years was used. The statistical analysis showed that positive correlations were found between drainage area, basin slope, and base flow. There were

some localized similarities with the base flow index (i.e., basins in the same area having the same base flow index), but it was not widespread. There was also no clear correlation between the sub-humid and the semi-arid regions in the study area.

This study determined that the recommended minimum period for a base flow study is 20 years or longer and that there are regional correlations between seasonal and decadal base flow trends, with the exception of a few basins that had anthropogenic affects.

Notice of Thesis Defense

MS Candidate: Wyatt Tatge

Program: Geology and **Geological Engineering**

Title: Water-quality analysis to evaluate effects of salinity on irrigation water in the Heart River Basin, North Dakota

When: Tuesday April 13th, 2021 8:00 AM

Where: Zoom video conference

Wyatt's research was conducted under the guidance of Major Professor Dr. Larry Stetler.

Abstract

Trends in water-quality for the Heart River Basin in west-central North Dakota were computed for historical (1974-2019) and recent (1999-2019) periods at 5 sites to determine changes that have occurred over time. Geochemical modeling was completed at these sites to determine the source of identified chemistry changes in the water. R-QWTREND was used to characterize dissolved ion concentration trends by removing the variability caused by changing streamflow conditions to determine changes from factors other than streamflow. EGRET was used to evaluate changes in streamflow throughout the basin. PHREEQC inverse modeling was used to better understand the geochemical reactions controlling water-quality within the Basin. Results of the EGRET simulations indicate increasing 7-day minimum flows resulting in increased groundwater discharge into the Heart River and its tributaries. Results of the trend analysis indicated that sulfate, sodium, calcium, potassium, magnesium, chloride, and total dissolved solids had increasing trends in either the historical or recent trend periods. Results of the geochemical modeling indicated that increased dissolved ion concentrations were derived mainly from sulfate evaporites that include gypsum, konyaite, mirabilite, and thenardite that are components in the soils and geology of the basin. Application of these results will assist producers and water-resource managers in making informed decisions regarding best management practices to protect soil health in terms of salinity and the quality of source water for irrigation.

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Notice of Thesis Defense

MS Candidate: Carson Reimers

Program: Geology and **Geological Engineering**

Title: Establishing methodology to generate three dimensional models of drilled core using close-range photogrammetry

When: Friday April 16th, 2021 12:30 PM

Where: Zoom video conference

Carson's research was conducted under the guidance of Major Professor Dr. Kurt Katzenstein.

Abstract

This study developed methodology to generate high resolution spatially oriented photogrammetric models of drill core. This included the fabrication of a photo acquisition rig for the purpose of acquiring closely spaced, overlapping photographs of drill core. The commercial software package, Agisoft™ Metashape Professional, utilized these photos to create photogrammetric models, in the form of dense point clouds, using computer vision techniques. These methods were applied to a dataset of 59-sampled core segments from eight boreholes, acquired from the EGS Collab experiment 1 on the 4850 level of the Sanford Underground Research Facility (SURF). These models are intended to be viewed, shared, and digitally archived indefinitely for use during the Collab project and after completion of the project. Model orientation methods have been developed with the use of commercial software package Maptek I-Site Studio 7.0. This allowed for the manipulation and reorienting of point clouds, correlation with borehole imagery and optical televiewer data, and measurement of fracture attitudes. Results of this study prove that core models can be successfully oriented and meaningful data can be extracted from them digitally that matches data acquired using more established technology. These models and orientation methods will allow for remote users to digitally examine core specimens in three dimensions with the anticipation that detailed analysis of core features will be possible. In the future, digital models such as these could be used as base models to overlay other ancillary core scanning or geophysical data, as well as the digital extraction of measurement of lithological and structural characteristics such as bedding and fracture orientations.

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Fall 2021:

Notice of Thesis Defense

MS Candidate: Mathew Weinberger

Program: **Geology** and Geological Engineering

Title: The Effect of Extensional Deformation on Gold Mineralization in the Fluorspar Canyon Region of Northern Bare Mountain, Nye County, Nevada, USA

When: Tuesday November 23rd, 2021 2:00 PM

Where: Zoom video conference

Mathew's research was conducted under the guidance of Major Professor Dr. Trevor Waldien

Abstract

In Fluorspar Hills region of northeastern Bare Mountain, southwestern Nevada, faulting began along the Fluorspar Canyon-Bullfrog Hills detachment fault at ca. 12.7 Ma and migrated westward causing tilting in the hanging wall which waned until ceasing at 8.2 Ma. This fault separates Miocene volcanic and volcano-sedimentary rocks of the hanging wall to the north from Paleozoic and Proterozoic sedimentary and metasedimentary rocks in the footwall to the south. The 11.55 Ma Twisted Canyon caldera, which lies about 3 km north of the detachment fault, is the other large-scale structure within the study area. The goal of this study is to determine which of these structures had the greater impact on extensional deformation in the area and their effect on gold mineralization within the hanging wall.

The study utilized bedding and fault attitude measurements as well as rock sample and drillhole Au assay values. Regions of similar bedding attitude measurements were used to identify four spatial domains in the study area: the NE, E, SE, and S-SW domains. Within each of these domains, percent extension along individual faults was calculated, as well as minimum and maximum extension for units in each domain. The extension calculations show that extension was up to twelve times greater on individual faults in the S-SW domain than the other three and that extension is correlated with proximity to the detachment. Similar to extension, Au concentrations for both rock samples and drillholes are correlated with proximity to the detachment fault. Drillhole Au values emulated this the most, after a distance of about 400 m from the detachment, Au concentration values approach zero.

Prediction surfaces were created using Empirical Bayesian Kriging and universal kriging for rock sample and drillhole Au concentration values, respectively. Interpolated values on the kriged surfaces were paired with locations of fault measurements and calculated, percent extension on individual faults. Only the rock sample data show a correlation with Au concentration. The correlation is most prominent for S-SW striking faults and those striking 100-120°. To a lesser extent, faults striking 020-040°, about 180° from the S-SW striking faults also show a correlation and may represent conjugate faults.

Overall, the geostatistical analysis suggests that the detachment fault is the main control on hanging wall deformation and Au mineralization in the study area. It is likely that the detachment acted as a direct conduit for subsequent mineralizing fluids that were also able to better permeate

the more extensionally deformed rock within the vicinity of the fault. Based on the above evidence and both rock sample and drillhole lithologies containing Au, it is likely that mineralization ended just prior to caldera collapse at 11.55 Ma or had waned significantly by then. Therefore, current evidence suggest that faults and fractures associated with collapse were unlikely to have served as conduits for mineralizing fluids.

Spring 2022:

Notice of Thesis Defense

MS Candidate: Colleen Sullivan

Program: Paleontology

Title: Fossil Dissolution Rates at Varying pH: A Pilot Study

When: Friday March 11th, 2022 9:00 AM

Where: Room 161 – Paleontology Research Lab and Zoom video conference

Colleen's research was conducted under the guidance of Major Professor Dr. Sarah Keenan.

Abstract

Fossils exposed at the surface are an integral component of paleontologic study. However, due to acidic precipitation, the long-term stability of these fossils is in question. One of the most abundant minerals found within bone is apatite. Fossil bone has been shown to exhibit three main apatite end members: hydroxylapatite, fluorapatite, and carbonated fluorapatite, each representing various stages of recrystallization of mineral bone (bioapatite). The dissolution of apatite is pH dependent, with dissolution increasing with decreasing pH. This characteristic of apatite dissolution becomes concerning in light of the acidic precipitation trends seen throughout the United States. Studies regarding the longevity of fossils subject to erosional processes, such as acidic precipitation, are absent in the literature. The goal of this study was to determine vertebrate fossil dissolution rates at varying pH to aid paleontologists in making better informed field collection decisions. It was hypothesized that fossils would dissolve within these acidic solutions and do so at an increasing rate when exposed to increasingly acidic solutions. It was also expected that dissolution would occur on the three-week time scale of the experiments.

Three fossil vertebrae (SDSM 010876) were selected and cut into thirds to conduct the experiment in triplicate. The experiment was completed in a closed reaction vessel. The fossils were completely submerged in a tap water solution with 0.1N hydrochloric acid (HCl) used to adjust the solution to the desired pH of 4, 5, or 6. The fossils were submerged for 21 days with the pH maintained manually by adding HCl to the system every two hours from 08:00 to 18:00.

Fossil dissolution was quantified by (1) mass loss; (2) differences in pre- and post-dissolution elemental water chemistry and fossil chemistry analyzed with inductively coupled plasma mass spectrometry (ICP-MS); (3) differences in pre- and post-dissolution fossil mineralogy analyzed with X-ray diffraction (XRD); and (4) thin section analysis of histologic structure degradation. All three fossils at each pH tested exhibited mass loss despite concomitant precipitate formation.

The ICP-MS results indicated elevated concentrations of both calcium and phosphorus released into the aqueous solution, suggesting dissolution of apatite, calcite, and gypsum. The phosphorus increases were indicative of fossil bone apatite dissolution since the apatite phases were the only minerals in this system expected to contain phosphorus. The XRD results indicated dissolution through the loss of gypsum in all post-dissolution samples. Thin section analysis showed degradation of trabeculae in all post-dissolution images, another direct measure of fossil bone dissolution. Batch reactions were done in PHREEQC to determine the molar transfer of the main fossil minerals—apatite, calcite, and gypsum—and indicated dissolution for the calcite and gypsum mineral phases. These findings constitute the first quantitative analysis of fossil dissolution rates that provide insights relevant to fossil conservation efforts, and a better understanding of preservation biases and taphonomic processes.

In addition to the dissolution experiments, revisions to current policies for approval of destructive analyses were proposed for potential use at the South Dakota School of Mines and Technology (South Dakota Mines) Museum of Geology (MoG). The proposed revisions call for increased documentation, implementation of statistical analyses to support requests, and introduction of required archival measures. Implementing these revisions would aid in making the destructive analysis approval process more consistent with other institutions as well as provide clearer protections to the MoG collections.

Notice of Thesis Defense

MS Candidate: Stephanie Loose

Program: **Geology** and Geological Engineering

Title: Fault Zone Characteristics and Epigenetic Gold Potential of the Holy Terror Gold Project, Keystone, South Dakota

When: Thursday March 24th, 2022 10:00 AM

Where: Room 321 – Mineral Industries Building

Stephanie's research was conducted under the guidance of Major Professor Dr. Timothy Masterlark.

Abstract

The Black Hills uplift of South Dakota consists of a core of Precambrian metamorphic and igneous rocks, overlain unconformably by a sequence of Phanerozoic sediments. The Precambrian core is highly complex, having undergone multiple deformation events since its deposition and uplift to the present-day position. Gold mining activity, which began in the Hills in the mid-1870s, has primarily taken place within this geologically complex core. This study investigates the relationship between deformational features and in-situ gold in a small site (just over 1 km^2) in the historic Keystone gold district. Four hypotheses are tested: that deformational and mineralogical features observed during field mapping are consistent with gold occurrence; that core from diamond drillholes in the region suggest deformational and mineralogical features consistent with gold occurrence; that thin sections obtained from the area show evidence of deformational and mineralogical features on the micro-scale that are consistent with gold

occurrence; and finally that the previous three analyses show self-consistent results that are consistent with gold occurrence. All four hypotheses were found to be true: mapping the surface, analyzing subsurface data from diamond drillholes, and examining micro-scales and mineralogy in thin sections all showed consistent results that supported the formation of epigenetic gold.

Notice of Thesis Defense

MS Candidate: Carolyn Kocken

Program: Paleontology

Title: Geographic and temporal variation in the morphology of diagnostic tooth characteristics in Mesohippus and Miohippus

When: Thursday March 31st, 2022 11:00 AM

Where: Room 328 – Mineral Industries Building and Zoom video conference

Colleen's research was conducted under the guidance of Major Professor Dr. Darrin Pagnac.

Abstract

Distinguishing Mesohippus from Miohippus has challenged paleontologists for many years as the diagnostic characters are vague and subjective. Unassociated cranial and postcranial material make linking identifying characters problematic. Based on these unclear diagnostic characters, many have argued for the synonymy of Mesohippus and Miohippus. Prior studies have supported this recommendation, but their research has been geographically and temporally limited. This study addresses morphologic variation among Mesohippus and Miohippus fossil teeth from four sites, John Day Fossil Beds National Monument in Oregon (30-23.8 Ma), Badlands National Park in South Dakota (37-23 Ma), Toadstool Geologic Park in Nebraska (37-30 Ma), and the Renova Formation in Montana (30-23 Ma), creating a larger and more geographically diverse dataset than in past studies. Utilizing nonparametric tests for significance, ordered logistic regression, non-metric multidimensional scaling, and bivariate plots, I analyzed the M1 and P4 occlusal surface for statistically significant groupings based on genus across the sites and North American Land Mammal Ages (NALMA). Additionally, hypostyle condition was assessed by genus, site, NALMA, and correlated with tooth height to determine variability in this feature. I have concluded that while there is some geographic and temporal variation, these genera should be synonymized, with Miohippus taking priority, and that hypostyle type is correlated with tooth height.

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Notice of Dissertation Defense

PhD Candidate: Brooke Long-Fox

Program: **Geology** and Geological Engineering

Title: Environmental and Phylogenetic Controls on Shell Morphology in the Chemosymbiotic Lucinidae (Bivalvia)

When: Wednesday April 6th, 2022 12:00 PM

Where: Zoom video conference

Brooke's research was conducted under the guidance of Major Professor Dr. Laurie Anderson.

Abstract

Lucinidae are the most specious family of chemosymbiotic bivalves and have a fossil record extending to the late Silurian. This dissertation examines how lucinid shell morphology, as described by categorical character states and using geometric morphometrics, corresponds with molecular phylogenies and endosymbiont relative abundances at several scales. First, congruence and resolution in molecular phylogenies versus those based on categorical shell character states is examined. A matrix of 58 shell characters and 52 species of lucinids from the Neogene and Quaternary of the Western Atlantic was used to construct morphological phylogenies that were compared to published molecular phylogenies. Results indicate phylogenies based on shell characters are often congruent with molecular phylogenies at the genus-level, although poorly resolved trees. Nonetheless, their addition provides a means to include extinct taxa in phylogenetic analyses. Second, morphological and phylogenetic relationships are examined using geometric morphometric analysis of shell interiors of eight lucinid species to test for phylogenetic signal in shape based on a landmark configuration focused on adductor muscle scars. Results confirm a strong phylogenetic signal in landmark data, however this signal does not represent shape variation of any particular morphologic feature(s). Third, population-level host molecular phylogeny, host shell morphology (geometric morphometrics), and endosymbiont relative abundances are compared in *Ctena* n. sp., which occurs in anchialine ponds and coastal lagoons of San Salvador Island, the Bahamas as well as in *Ctena orbiculata* from coastal Florida and San Salvador. No differences in sequence data among populations were found, although there were significant differences in both host shell morphology and endosymbiont diversity by locality, whereas host shell morphology and endosymbiont diversity are not significantly correlated. This dissertation provides 1) a new phylogeny for lucinids incorporating morphological characters, 2) the first use of COI in a molecular phylogeny for the family, 3) the first test for phylogenetic signal in lucinid morphology, 4) the first test of a relationship between host morphology and endosymbiont diversity, and 5) a description and support for a new species of *Ctena*. In conclusion, interpreting morphology is complex, as it contains both phylogenetic and environmental signals.

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Notice of Thesis Defense

MS Candidate: John Hewitt

Program: **Geology** and Geological Engineering

Title: Petrogenesis of Plagioclase Ultraphyric Basalts (PUB) from the Northeastern (NE) Pacific Ridge System: Evidence from Mineral Textures and Geochemical Characteristics

When: Monday April 11th, 2022 1:00 PM

Where: Bump Lounge – Surbeck Center and Zoom video conference

John's research was conducted under the guidance of Major Professor Dr. Gokce Ustunisik.

Abstract

Plagioclase crystals in plagioclase ultraphyric basalts (PUB) record changes in the major, trace, and isotopic compositions of magmas as they evolve. Those changes represent the signature of specific processes active in the crust and upper mantle that impart distinct crystal textures onto which the chemical signature is written. Recently a study of the textural and compositional associations for PUB from the Gakkel Ridge (Bennett et al., 2019), an ultra-slow spreading ridge (<1cm/yr.) in the Arctic, documented textural features linked to specific processes (mixing, fractionation, resorption, etc.). However, the extent to which associated textures and chemical signatures from one tectonic setting to another is unclear. Here we report on the textural compositional characteristics of lavas from the Northeastern (NE) Pacific Ridge System PUB lavas (Endeavor and West Valley segments of the Juan de Fuca Ridge, Blanco Fracture Zone, and the Gorda Ridge) and compare our measurements with those reported for the Gakkel Ridge samples (crystal morphology, size, phase assemblage, zoning, etc.). These ridge systems represent faster spreading rates (~6 cm/yr.) and a range of higher magma supplies compared to the Gakkel Ridge (low magma supply and heterogeneous mantle source material). Based on the major element analyses, the NE Pacific Ridge system exhibit a variety of populations of plagioclase megacrysts as characterized by An mole %, MgO, TiO_2, and FeO. These characteristics (single mode, bimodal, or trimodal distribution) are consistent with the presence of more than one parental magma in some samples. The trace element composition of the megacrysts exhibit the same level of heterogeneity previously observed in these megacrysts and their host lavas from the NE Pacific indicating multiple sources, processes, and residence times (Nielsen et. al., 2020; Ustunisik et al., 2021). What we have found in this most recent investigation is that there is sometimes a clear correlation of texture with major and trace element composition of the megacrysts – but that relationship is not always present. This raises the question of why texture and composition are linked in some settings but not others, and what might that tell us about the differences between ridge systems (parental magma diversity, plumbing system, magma supply and depth at which magmas undergo mixing).

SOUTH DAKOTA MINES
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Notice of Dissertation Defense

PhD Candidate: Fleford Redoloza

Program: Geology and **Geological Engineering**

Title: The Use of Deep Learning for Hydrogeological Inverse Modeling in Channelized Aquifers

When: Tuesday April 12th, 2022 2:00 PM

Where: Dorr Room – Surbeck Center

Flefords's research was conducted under the guidance of Major Professor Dr. Liangping Li.

Abstract

One of the most important tasks in hydrogeology is inverse modeling. Inverse modeling refers to the task of integrating observation data sampled from the field into geologic models that can be used in a wide range of applications such as planning well-pumping schedules of aquifers and predicting the migration of contaminant plumes. The main challenge in inverse modeling is to honor the measured data as well as the geologic structures, especially for complex geologic deposits such as channelized aquifers. To deal with this challenge, deep learning methods have recently been employed to model the geological model by conditioning on measured data. Popular deep learning techniques include convolutional neural networks (CNN) and generative adversarial networks (GAN). This study provides a deeper understanding of how CNN and GAN perform within the context of hydrogeological inverse modeling. The first set of numerical experiments was conducted using conditional progressive growing GAN (PGGAN) to generate realistic images of channelized aquifer models that honor both field observations (the conditioning data) and the conceptual model. A metric was developed to quantitatively measure the impacts of the number of conditioning data on the quality of generated images. The results revealed non-intuitive trends between the PGGAN model conditioning behavior and its hyperparameters. The second set of experiments involved training a GAN model capable of making semantically intuitive and geologically realistic images through spatial adjustment of the GAN's latent variable. The results indicated that this latent variable adjustment allows for faster and computationally more efficient inverse modeling. The final set of experiments was designed to study the generalization issues of CNN, especially within the context of hydrogeology. An image segmentation CNN model (i.e., UNet) is trained to solve a range of critical hydrogeological problems such as connectivity of hydraulic conductivities. The trained UNet model was then tested on problems vastly different from what they were trained on. The results show that CNNs are sensitive to image rotations and that there are data augmentation operations that are less useful for training models than expected. In summary, a set of deep learning tools was developed in Python and demonstrated using synthetic examples for hydrogeological inverse modeling, and the results of numerical experiments guided us to a better understanding of how CNN and GAN perform in the context of hydrogeology.

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Notice of Thesis Defense

MS Candidate: Erica Cung

Program: **Geology** and Geological Engineering

Title: Quantitative Analysis of Trace Element Partitioning Data for Clinopyroxene, Garnet, and Amphibole Using Statistical Methods

When: Tuesday April 12th, 2022 11:00 AM

Where: Dorr Room – Surbeck Center and Zoom video conference

Erica's research was conducted under the guidance of Major Professor Dr. Gokce Ustunisik.

Abstract

Our understanding of the differentiation of the terrestrial planets is based on models of the behavior of trace elements under changing conditions. Such models simulate how differentiation processes influence the trace element composition of evolving natural materials. Such predictive models require knowledge of trace element behavior among coexisting phases including melt, crystal, vapor, and fluid over a range of natural conditions. Trace element partitioning is dependent on several parameters including pressure (P), temperature (T), and composition (X). Models are based on the results of laboratory experiments designed to develop equilibrium mineral/melt pairs under controlled conditions and are accessible from existing databases (https://www.earthchem.org/). However, if the data coverage is variable (e.g., different trace elements were analyzed in different experiments of varying X, P, and T), the regression constants that describe dependencies for trace element partitioning in each phase will be based on different experimental datasets. The goal of this research is to evaluate how partition coefficients (D_i) correlate with a variety of intensive and compositional variables as a function database characteristics and differences in the substitution mechanisms by which trace elements are included in three of the phases (clinopyroxene, amphibole, and garnet) that control the trace element budget of the upper mantle and crust. Our results show that the number of experimental determinations, even within a group of elements that behave systematically (e.g., REEs), may vary a factor of five - ten. Further, the average temperature and pressure for the experimental conditions may vary by 100s of ^{o}C and 2-5 kbars between experimental determinations of elements for the same mineral. In spite of these differences in database characteristics, there is evidence for systematic variations as a function of composition, temperature, and pressure. For example, the correlation of D for REE and HFSE in clinopyroxene and amphibole with tetrahedral aluminum (Al_{IV}) and D_{Ti} are similar despite the difference in valence. The temperature dependence of REE partitioning (as approximated by the slope of D_{REE} vs. 10000/T) in clinopyroxene, amphibole and garnet is correlated with ionic radius. The trend is negative for clinopyroxene but positive for amphibole and garnet. Departure from that trend is negatively correlated with the number of experimental determinations for each element, suggesting some underlying cause related to how those experiments were planned and conducted.

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Notice of Thesis Defense

MS Candidate: Michael Cyrier

Program: Paleontology

Title: The Impact of Carbon Availability and Geochemical Variation on Habitability of Epigenic Cave Systems

When: Wednesday April 13th, 2022 12:00 PM

Where: Room 161 – Paleontology Research Laboratory and Zoom video conference

Michael's research was conducted under the guidance of Major Professor Dr. Sarah Keenan.

Abstract

Caves are unique environments that sustain ecosystems independent of photosynthetic primary production and are heavily influence by the geochemistry of the geologic units they are formed within. This study investigated five epigenic cave systems in the Black Hills of South Dakota—Rushmore Cave, Bethlehem Cave, Stagebarn Cave, Dahm Springs Cave, and Brooks Cave—with the goal of defining microbial habitability. Habitability, defined as the potential for live to thrive or survive, was determined by examining the physical, biological, and geochemical composition of waters and sediments within five caves. Microbial respiration rates and DNA concentrations in cave sediments were used to define biological activity. Microbial respiration rates within sediments was found to strongly correlate with organic carbon content (p-value = 0.004) through Spearman Rho tests but did not significantly correlate with DNA concentration. The correlation between microbial respiration rate and organic carbon content can be attributed to heterotrophic activity. However, for chemoautotrophic bacteria in caves to gain energy primarily though biomineralization of $CaCO_3$ from inorganic carbon, cave waters should be supersaturated with respect to $CaCO_3$. Every pool that was sampled in this study was supersaturated with respect to calcite and aragonite, increasing the potential habitability for chemoautotrophs. Trace metal data also provide important constraints on potential metabolisms active in each cave, such as reduction of Fe^{3+} to Fe^{2+}, Mn^{4+} to Mn^{2+}, and the precipitation of metal-bound carbonate minerals siderite ($FeCO_3$), rhodochrosite ($MnCO_3$), witherite ($BaCO_3$), and strontianite ($SrCO_3$). In order to compare the subsurface environmental conditions between these caves, a principal coordinates analysis was conducted. This found that each cave was distinct from one another based on geochemical data despite being present in the same geologic unit, the Pahasapa Formation. Some of the most important distinguishing parameters of the caves were the sediment organic and inorganic carbon content, dissolved organic (TOC) and inorganic (TIC) carbon in pool water, CO_2 concentration in the air, and various dissolved ion concentrations. Distance between caves did not play a major role in the variability of the subsurface environments between the caves. Surface sediment chemistry and microbial activity above each cave did not correlate with subsurface sediments within each cave. Additionally, tourism was found to heavily impact the cave environment in Rushmore Cave through increased CO_2 concentration from visitor respiration, introduction of dissolved metals from pollutants (coins) in the pools, and elevated amounts of NO_3^-. However, caves that were previously open to tourism several decades ago (Bethlehem Cave and Stagebarn Cave) had similar environmental conditions to a completely undeveloped cave (Brooks Cave). The results of this study provide

important insights into the potential habitability of Black Hills caves by microorganisms. Additionally, these results provide context for future studies of microbial diversity with Black Hills caves, and for exploring the limits to life in nutrient-limited ecosystems.