AESRC 2019 Oral Presentation
Session 1: Quaternary Science
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A New Stimulated Luminescence Dating Lab at the University of Ottawa

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Frequently applied in Quaternary geochronological studies, stimulated luminescence dating is a versatile, non-destructive dating method based on dosimetry. In its many forms, it can be applied to determine burial ages of aeolian sediments, cooling ages for volcanic materials, or even surface exposure ages for hard rock outcrops. The dating principle relies on the omnipresence of radioactive trace elements constantly emitting ionizing radiation that slowly damages its surroundings by dislodging electrons in the crystalline structure of minerals like quartz or feldspar. Some of these electrons become trapped in metastable states, with the number of trapped electrons growing over time. Stimulating samples of crystals or sediment using either heat or light causes the trapped electrons to return to their stable state, emitting photons of a known wavelength that can be measured as a luminescence signal. These measurements are thermoluminescence (TL) or optically stimulated luminescence (OSL) depending on the method of stimulation. The measured luminescence signal is proportional to the ionizing radiation dose accumulated in the sample, and with an independent determination of the sample's in-situ dose rate, these dose measurements are converted to ages. Since 2017, preliminary operations have been underway to establish a new stimulated luminescence laboratory at the University of Ottawa. Set up in a darkroom, the laboratory has been developing the capabilities to process ancient sediment samples for dating by OSL and TL. To date, a Riso DA-20 TL/OSL reader has been installed and commissioning tests are ongoing. These tests include a calibration of the internal dose rate of an integrated Sr-90 irradiator, as well as studies of the instrument's performance and reproducibility. Future work will be discussed including proposed geochronological investigations of a permafrost section in the Canadian arctic and ancient lacustrine shorelines in Antarctica.

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Micro-XRF geochemical and micropaleontological evidence for prehistoric land disturbance: construction of the Middle Woodland (ca. 300 BCE–700 CE) Serpent Mounds complex, Rice Lake (Ontario, Canada)

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Serpent Mounds is a prehistoric (Middle Woodland, ca. 2000-1000 BP) burial mound complex located on the north shore of Rice Lake (Ontario, CA). The complex includes a 60m long and 10m wide sinuous earthwork ridge and eight oval mound structures. The timing of mound construction is poorly constrained limited radiocarbon dates on human burials, and sparse paleoenvironmental data. Serpent Mounds is of high cultural importance as the only known effigy mound structure in Canada; no further excavations are permitted onsite and all future work must employ non-invasive techniques.

XRF Core Scanning and micropaleontologic analysis (testate amoebae) of 12 lake sediment cores was employed to investigate the timing of mound construction and assess prehistoric land disturbance. Land disturbance is indicated by increasing minerogenic elements (K, Ti, Zr, Si, Fe) within a distinctive silt-rich gyttja unit. Heightened terrigenous sediment influx coincides with abundant D. oblonga, C. tricuspis, and D. proteiformis, indicating a more eutrophic, turbid lake environment. Principal component analysis and cluster analysis of µ-XRF data identifies the event as a distinctive chemofacies across several cores. AMS 14C dates for the land disturbance event correspond with the Point Peninsula occupation of sites around Serpent Mounds, indicating a protracted occupation over from 2050–1300 cal BP with two major peaks in soil erosion at ca. 2200 and 1350 cal BP. The sediment accumulation rate (> 1.5mm/yr) during the phase of enhanced erosion was comparable to that during the 1838 CE dam construction.

The reconstructed Middle Woodland paleoshoreline and water levels indicate shallow lake and wetland and environments, which provided suitable habitats for the growth of wild rice stands and shellfish resources. The results demonstrate that XRF Core Scanning and micropaleontological methods are important tools for the investigation of culturally-sensitive archaeological sites.

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The relative role of internal and external factors on Holocene carbon accumulation in a Hudson Bay Lowland peatland, northern Ontario

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The Hudson Bay Lowlands (HBL) is a vast continuous peatland region and an important area to study the impact of internal and external factors on long-term carbon accumulation in order to better understand these ecosystems response to future climate change. A Sphagnum bog site within the southern James Bay region of northern Ontario was selected to better understand the relative roles of climate, hydrology, and succession on Holocene carbon accumulation, using pollen, non-pollen palynomorphs, testate amoebae, plant macrofossils, and peat properties as proxies. The site was initially a marsh ecosystem approximately 7200 cal yr BP, followed by a transition to an open fen. A transition to a poor fen with more shrub cover is indicated by increased Betula and Sphagnum abundance after 2600 cal yr BP. Testate amoebae are generally absent from the record until the rich to poor fen transition, signifying an environmental control on preservation. The site remained under fen-like conditions with herbaceous-dominated peat until after 1300 cal yr BP and was characterized by low carbon accumulation rates (3.5 to 15.3 g C/m^2/yr), despite warmer conditions in the Middle Holocene that would promote higher net primary productivity. The highest carbon accumulation rates in the record (24.8 to 28.9 g C/m^2/yr; from 340 to 920 cal yr BP) are associated with a shift to Sphagnum-dominated peat, a higher rate of peat accumulation, and warmer temperatures during the Medieval Climate Anomaly, which suggests a role of both climate and succession on carbon accumulation. This record demonstrates the importance of local-scale factors on carbon accumulation rates in peatlands and the need for more paleoecological records in the region to understand peatland carbon variability across the landscape.

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The role of groundwater and subsurface hydrological processes in reconstructing the Green Sahara

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During the Mid-Holocene, the Sahara region of Africa experienced a significantly more humid climate due to a precessionally-driven northward shift of the Inter-Tropical Convergence Zone. However, the majority of paleoclimate models are unable to reconstruct a climate that is humid enough in this area to coincide with paleoenvironmental evidence and data. Additionally, many climate models also fail to consider groundwater flow and associated subsurface hydrological processes, which may affect model accuracy and explain the moisture discrepancy. The objective of this study is to determine whether the inclusion of groundwater in Earth System Models will provide a more accurate reconstruction of the Green Sahara. This is accomplished through comparing simulated African equilibrium water table depths (EWTDs) from 6ka to several paleoenvironmental data assemblages. This study concludes that the correlation between EWTDs and paleoenvironmental data is strong in numerous regions but is overall inconsistent. More research must be conducted to further improve the parameters of the EWTD simulation, which may in turn improve the accuracy and precision of 6ka EWTD simulations.

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Fire and Low CO_2 Open Amazonian Dry Corridors

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We present integrated modeling evidence for a grassier, less forested Neotropics during the Last Glacial Maximum (LGM), congruent with palaeoecogical and biological studies, and grounded in the fire-mediated dynamics of forest-savanna boundaries. High-resolution model reconstructions of vegetations were generated using the Land Processes and eXchanges (LPX) vegetation model, driven by four climate model reconstructions of LGM climate, and tested against a body of palynological data. A factorial experiment was performed to quantify the impact of fire processes and low CO_2 on modeled vegetation and model-data agreement. Fire processes and low atmospheric carbon dioxide were both found to induce widespread expansion of savanna and grassland while improving model-data agreement. The interactive effects of fire and low CO_2 were found to induce the greatest 'savannafication' of the Neotropics, providing strong modeling evidence for a number of biologically relevant open vegetation formations including two 'dry corridors'; paths of savanna through and around Amazonia that facilitated major dispersal and diversification events. Our results suggest forest and savanna to be alternate stable states as fire was also found to induce the bimodality of tree cover, which was further enhanced by the effects of low CO_2.

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AESRC 2019 Keynote Talk
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Neoproterozoic deep-marine phosphatic deposits in southern Canadian Cordillera: Phosphogenesis and paleoceanography

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Significant phosphatic-rich deposits, or phosphorites, were formed worldwide during the mid-Neoproterozoic to early mid-Cambrian, and most notably during the Ediacaran (late Neoproterozoic). Recently reported are phosphate-rich beds that have P2O5 content ranging up to 15%, which are variably intercalated with siliciclastic, deep-marine, thin-bedded turbidites of the late Neoproterozoic Windermere Supergroup in the southern Canadian Cordillera. Microtextural and compositional analyses of these beds suggests that they formed from detrital phosphate grains formed in shallow-water marine environments, but that were transported and resedimented downslope from the continental shelf onto slope and more distal deep basin floor and later recrystallized extensively during early marine phosphogenesis. The discrete, but more importantly recurrent occurrence of these phosphate-rich beds, could help constrain the key chemical and paleoceanographic conditions in the global oceans during the Neoproterozoic, and more specifically the input of phosphate from intensified continental weathering and/or oceanographic upwelling events.

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Seawater contamination in ODP/IODP porewater samples and its quantitative effects on studies of microbial sulfate reduction

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Redox reactions at the seafloor determine how much organic carbon is buried and thus play vital roles in regulating the carbon and oxygen cycles on Earth. Studies usually reveal the extents of these redox reactions by measuring the concentrations of dissolved reactants or products in porewater, followed by modeling or incubation. Measuring porewater chemicals has been a standard practice in expeditions of the International Ocean Discovery Program (IODP, and formerly the Ocean Drilling Program (ODP)). However, porewater is prone to contamination, especially to seawater which comprises the ambient environment and is used as drilling fluid. As seawater contains a high content of sulfate (28 to 29~mM), a small quantity of seawater can already add a large amount of sulfate into porewater samples and impede the reliability of studies on subseafloor sulfate reduction. However, descriptions of such effects from contamination have largely been qualitative. We study the quantitative relationship between the amount of seawater and the resulting rates of sulfate reduction and isotopic fractionation with reaction-transport models and give suggestions to avoid or discern contamination.

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Understanding the impact of largescale flood events on the structure and stability of the latero-frontal moraine at Gígjökull, Iceland

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The increase in global temperatures has caused a rapid retreat of glaciers worldwide and an increase in glacial meltwater flow. This higher level of glacial meltwater discharge into overdeepened basins has increased the number and size of moraine-dammed glacial lakes. The increase in number of these lakes and the unstable nature of the moraine dams has in turn raised the risk of potential catastrophic floods known as glacial lake outburst floods (GLOFs). Understanding the sedimentology, architecture and integrity of these moraines is essential for risk mitigation in many glaciated regions where communities live.

This study focuses on the structure of the laterofrontal moraine at Gígjökull, an outlet glacier of the Eyjafjallajökull Ice Cap in southern Iceland. Gígjökull experienced multiple large scale flood events after the 2010 eruption at Eyjafjallajökull and illustrates how moraines are impacted by these events. To characterize the structure of the laterofrontal moraines a combination of geomorphological and sedimentological analysis was applied. Aerial imagery retrieved from Google Earth from pre and post flood time periods was used to map the evolution of the geomorphology caused by the flood event. Using a DJI phantom 4 unmanned aerial vehicle (UAV) high resolution imagery was collected of the left frontal moraine. This imagery was processed using Agisoft Metascan to create high resolution digital elevation model and orthophotos. Sedimentological data, including six detailed sediment logs, was collected along the moraine. These two datasets are combined to create a three-dimensional understanding of the structure of the moraine which can be connected to its stability. The results of this study can be used as an analogue, and for comparison, in other regions prone to GLOFS such as the Peruvian Andes, the Canadian Rocky Mountains and the Himalayas to inform policy and infrastructure to protect at risk communities.

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Investigating the impact of fast ice flow on the landform-sediment assemblages in the proglacial fields of Sléttjökull and Öldufellsjökull, Mýrdalsjökull Ice Cap, southern Iceland

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The increase in global temperature has resulted in the rapid retreat of glacier margins exposing landforms which record changes in glacier extent and behaviour through their sedimentology and geomorphology. These modern systems can be used as analogues for paleoglacial deposits, such as those found throughout southern Ontario, and used to interpret paleoglacial dynamics. The location and size of ice streams, areas of fast flowing ice, in ice sheets are important factors in controlling ice behaviour and dynamics. However, determining their location in paleoglacial environments can be difficult. Modern surging glaciers which undergo periodic rapid ice flow events have been proposed as analogues for paleoice streams in the Laurentide and Scandinavian Ice sheets.

This study focuses the geomorphology and sedimentology of western Sléttjökull and Öldufellsjökull, two surge-type outlet glaciers of the Mýrdalsjökull Ice Cap in southern Iceland. This study uses landsystem analysis and architectural element analysis to create a detailed understanding of the process-form relationship of landforms and sediments exposed in the proglacial fields. Initial mapping of the glacier was completed using a digital elevation model (DEM) and aerial imagery of the study sites. High resolution imagery was collected using an unmanned aerial vehicle (UAV) at specific sites of interest impacted by the most recent surge events. This imagery was input into Agisoft Metascan to create DEMs and orthophotos of the study sites. Sedimentological data were collected from exposures along river banks to identify sediment types associated with different landforms. The field and remotely sensed data were combined to create an understanding of the distribution and relationship between the landforms and sediments. The model developed for these proglacial fields may be utilized to help identify areas affected by fast-flowing ice and the position of former ice streams in previously glaciated regions.

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Unmixing Mixed Signals in Ancient Fluvial Deposits: Implications for Paleogeographic Reconstructions and Sedimentary Provenance Sampling Strategies

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Distinct changes in sediment provenance have been documented within a single channel complex of the Late Cretaceous Gallup Sandstone Formation in northwestern New Mexico, using a combination of detrital zircon data (n=504) supplemented with modal sandstone compositions (n=3768). At the base of the channel complex the detrital zircon ages are mixed, with no major peaks in any age, which is indicative of recycled Sevier fold-and-thrust belt sediments. The upper channel, however has an overwhelming source of 1.6-1.8 Ga zircons which is the signal for the nearby Mogollon Highlands to the south. The petrographic data further establishes this change in source due to the high amount of lithic fragments found in the lower channel, specifically volcanics from the Cordilleran Magmatic Arc to the southwest and sedimentary lithic fragments recycled from the Sevier Orogeny to the west. The upper channel however, contains recognizably less lithics and an increase in feldspathic minerals likely from the uplifted basement rock of the Mogollon Highlands. This loss of sediment derived from the west/southwest through time is attributed to forebulge migration from west to east through this retroarc foreland basin. Tectonic forcing and subsequent increases in sediment supply are likely a more dominant allogenic influence on regional-scale stratal architectures than eustatic processes during the Cretaceous greenhouse period which is dominated by low amplitude, frequent changes in sea level; compared to modern icehouse periods which are dominated by high amplitude, frequent eustatic variations. This study also emphasizes the importance of collecting multiple (N= >1) samples in provenance studies as sources can change drastically within a single seemingly continuous fluvial succession.

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The effect of aseismic slip on the source processes of induced seismicity: Advancing or delaying the next earthquake?

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Earthquakes with an anthropogenic origin have occurred at an unprecedented rate and raised global concern in recent years. The key to effectively mitigate the associated seismic hazard is a thorough understanding of the triggering mechanisms of induced earthquakes. Various mechanisms have been proposed, including the direct effect of fluid present on the fault and the change in loading due to poroelastic stresses. More recent studies also suggested complex driving forces that involve aseismic motion on the fault. The interplay of seismic and aseismic on triggered faults is intriguing because of the evolving state of stress during and after the injection.

In this study, we aim to characterize, through numerical simulations, the aseismic motion on a fault that is subjected to fluid-induced stress perturbation. We consider the effects of aseismic slip on both the timing and size of the induced seismic events. Our fault model is governed by the empirically-derived rate-and-state friction laws and features a velocity-weakening (VW) patch embedded in a large velocity-strengthening (VS) region. It is subjected to various levels of poroelastic-stress or pore-pressure perturbations at different times during a selected seismic cycle. The key finding of our study indicates that, while fluid injection is generally believed to trigger the next event to occur sooner, i.e. advancing the seismic cycle, injections on faults that are susceptible to substantial aseismic slip may actually lengthen the seismic cycle and delay subsequent seismic events. In other words, the induced aseismic response is capable of both stabilizing and destabilizing the fault. In particular, the delaying in triggering tends to happen when the level of stress perturbation is low (0.1 – 0.2 MPa) and when the perturbation occurs late in the interseismic period (80 – 85%). Our model shows that the state of stress of the VW patch at the moment of perturbation and the critical nucleation size of the fault are important factors that determine the extent of aseismic response on the fault and timing of the subsequent (triggered) event.

Our ongoing work is to better quantify the aseismic response caused by different types of induced stress perturbation and to investigate the aseismic response of faults in subsequent earthquake cycles. We aim to better constrain the range and timing of stress perturbations that are favorable for inducing earthquakes. The subsequent step is then to incorporate specific fluid injection histories and fault frictional properties to model and explain field observations.

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Time-Series Approach to Remove Severe Noise from Airborne Time-Domain Electromagnetic Data Acquired in New Brunswick, Canada

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This study focuses on an area northwest of Bathurst Mining Camp where there is great interest for base metal (Zn, Pb, Ag) exploration. Due to dense vegetation and swamps covering the land in certain parts, Airborne Time-Domain Electromagnetic (TDEM) systems have been employed to survey the area. One survey, flown in April 2004, collected 272 kilometers of vertical (Z) and horizontal (H) component data. Complications in the data set arose from unconventional pole-mounted powerline transmitters used to carry large voltages into isolated areas. The noise response from these transformers overpowers the geological background response resulting in contamination of derived products making it difficult to identify real targets of interest. The limited use of these transformers limits previous work done to remove such noise from data and the development of a successful method could then be applied anywhere stationary transformer powerlines are encountered. By using a time-series approach, we analyze the unique stationary noise pattern and characterize the amplitude and phase response of the noise in order to design a filter to remove the noise effectively. The cleaned data from this project can then be used to create accurate decay constant and conductivity maps of the 39.6 km^2 area.

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Spurious transitions in convective regime due to viscosity clipping: Ramifications for modelling planetary secular cooling

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The thermal evolution of planetary mantles is widely studied in systems governed by the Arrhenius viscosity law. For typical silicate compositions and temperature ranges, the Arrhenius law's temperature dependence often yields viscosity gradients across the mantle depth that are intractable to emulate in a numerical model. In this study, over a span of five billion years we investigate the effect of viscosity clipping (i.e., limiting the maximum value of the viscosity) on the thermal evolution of lunar-sized initially hot bodies featuring decaying internal heat sources. Models with a decreasing viscosity contrast obtained by limiting the maximum viscosity to 10^5.5 times the core-mantle-boundary viscosity were first examined. For cases with moderate or no internal heating, rapid cooling was observed as a result of a convective regime change from stagnant-lid to mobile lid convection followed by gradual cooling to a nearly conductive state that inherited a thermal convective signature. Subsequently, we model a constant viscosity contrast employing a dynamic clipping viscosity of $10^{5.5}$ times the core-mantle-boundary viscosity throughout the planet's lifespan. Making this adaptation, stagnant-lid convection was the only convective regime observed; gradually evolving to a state emulating conduction with internal heat sources. Finally, convection with an initially large viscosity contrast (10^{10}) was modeled and we found strong agreement in the thermal evolution compared to the dynamic clipping model. This finding has implications for whether convective regime changes are spurious and result from conservative viscosity limiting. Our calculations show for the geometry considered thermal evolution differs in 2D and 3D models only when transitions to mobile lid convection occur.

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Characterizing the Microstructural Response of Impact-related Deformation in Lunar Anorthosite Breccia North West Africa 10272

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U- and Th-bearing accessory phases, such as zircon and baddeleyite, demonstrate increasing potential as indicators of impact-related shock metamorphism in lunar meteorites. However, the microstructural response of these minerals to extreme pressure and temperature conditions is still loosely constrained. In this study, we use chemical and orientation micro-structural techniques to analyze zircon and baddeleyite grains in anorthosite breccia North West Africa (NWA) 10272. The combination of these techniques can be used to characterize the pressure-temperature trajectories experienced by their primary lithologies. Automated electron beam identification of zircon and baddeleyite reveal variable size and distribution of grains in the aluminum-rich matrix and primary lithic clasts. Oscillatory cathodoluminescence (CL) banding within zircon is interpreted as primary igneous growth banding. Zircon electron backscatter diffraction (EBSD) maps show a single crystallographic orientation and do not contain evidence of microstructures indicative of shock. A non-luminescent core of one zircon does not index in CL or EBSD and is interpreted to be metamict. Baddeleyite grains are primarily subhedral to anhedral and exhibit weak planar CL bands that are less than 1 μm in width. In colour CL, grains are characterized with bright outermost rims with alternating, irregular non-luminescent zones in the interior. EBSD maps reveal a range of orthogonally-related crystallographic orientation clusters in <100>, <010>, <001> pole figures. Two grains preserve common “cross-shape” relationships in <001>, indicative of reversion from high-symmetry polymorphs. Not only does the sequence of shock deformation within these accessory phases demonstrate significant impacts on the lunar surface, they also aid in interpretations of duration and rate of bombardment in the inner Solar System and help place constraints on the habitability of the early Earth.

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A Quantitative Analysis of Sorted Patterned Ground within the Haughton Impact Structure, Devon Island, with Implications to Mars

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Permafrost underlies 24% of the Earth's land area and is a major control for the generation of patterned ground and other terrain anomalies that can also be found on Mars. The study area in Devon Island, located in the Canadian High Arctic, is in the continuous permafrost zone where periglacial features are widespread. Patterned ground, specifically sorted stone circles, are periglacial features of interest that can provide insight into past climate, water availability, and geologic substrate on both the Earth and Mars. In this study, we test a quantitative remote sensing methodology coupled with understanding periglacial landform evolution with implications to Mars to identify spatial variance and sorting of different stone circle morphologies in a remote sensing and Geographical Information System (GIS) interface. Spatial modelling of geomorphologic landforms and processes is currently one of the prevailing issues in geomorphology. Remote sensing provides an opportunity to collect spatially continuous information on environmental determinants of sorted patterned ground. Data was acquired in late July 2017 using a high resolution UAV, tripod LiDAR scans, and a novel backpack-mounted Kinematic Mobile LiDAR scanner (KLS). After processing the (~1–5 cm/pixel) LiDAR data, we carried out a geomorphometric analysis using kernel estimation and cumulative sorting analysis. Quantitative analysis of the form and spatial distribution of sorted stone circles within the Haughton Structure identifies a number of distinctive patterns that reflect spatial variability in processes responsible for their formation as well as the presence and amount of ice. There are several factors that control sorted stone circle morphology. Microtopography, water/ice availability, and the cyclic burial and exhumation of sediments/rocks is believed to play an important role in the sorting and spatial distribution of stone circles, which can then be used to determine periglacial surface kinematics.

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Using Highly Siderophile Elements in Ureilites to Better Understand Asteroid Formation Processes

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Ureilites are a unique group of ultramafic achondrite, composed of olivine and pigeonite silicate phases, interstitial metals, and carbon polymorphs, graphite, and diamond. They are derived from interior silicate portions of the disrupted ureilite parent body and likely formed from the mixing of two distinct reservoirs. They are residues of partial-melting evident from a lack of plagioclase, low abundances of incompatible trace elements, and fractionated rare earth element (REE) and highly siderophile element (HSE) patterns. HSE are metal-loving and highly refractory rendering them excellent tracers of cosmochemical processes. Their high compatibility in metals and sulfides makes them valuable in ureilite research.

Our primary objective is to further constrain the petrogenesis of ureilites focusing on the diamond-rich Nova 018 (Nova). Nova is highly reduced with wide metal-rich reduction rims surrounding the silicates. Carbon appears as clustered lath-like domains between silicate phases but appears to have a higher affinity to pigeonite and is nearly always found in reduction rims. Oxygen isotope analysis gives mean $\Delta^{17}O$ of -0.327 ± 0.007‰ with $\delta^{17}O$ = 4.192‰ and $\delta^{18}O$ = 8.580‰ positioning Nova near the isotopically 'heavy end' of the known ureilite group.

REE and HSE abundances of silicates and metal grains were measured by laser ablation inductively coupled plasma mass spectrometry. Silicate REE contents are similar to previously reported data. Metals show high HSE abundances of ~0.5-18 x Carbonaceous Ivuna chondrite with similar bulk rock patterns, but with higher absolute abundances. Bulk rock HSE patterns are similar to other ureilites with marked depletion of Re in likely due to terrestrial alteration. This manifests as a strongly fractionated $^{187}Re/^{188}Os$ (0.208), which is significantly lower than most ureilites or chondritic materials. $^{187}Os/^{188}Os$ (~0.126) are like other measured ureilites and suggest a carbonaceous chondrite like pre-cursor.

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Identifying the Effects of Shock on the Composition of Martian Phosphate Minerals Using Correlative Structural and Chemical Techniques

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Determining when and if habitable environments existed on Mars is a major focus of planetary science research, the answers to which will directly influence our understanding of life on Earth, Mars, and throughout the Solar System. While evidence from rovers and remote sensing analyses have confirmed that water was once widespread across the Martian surface, the presence of water alone is not enough to confirm if the conditions necessary for life were once present. A detailed understanding of the timing of magmatism, bombardment, water, and phosphorous availability are all essential. This study focuses on Martian phosphate minerals as they have been studied extensively as reservoirs of water, sources of bio-essential phosphorous, and geochronometers. However, at this time no Martian samples have been directly retrieved from the planet's surface, restricting our analyses to shock-deformed meteorites that have undergone intense deformation during violent impact and ejection from the Martian surface. These shock events can cause mineral transformations, chemical reactions, and loss of volatiles and isotope species through transient, high-diffusivity pathways. As the effects of shock on the composition and structure of phosphate minerals are poorly understood, here we aim to document the chemical compositions of phosphate minerals over a range of shock conditions (from relatively pristine "unshocked" samples, to over 75 GPa and 1500oC) allowing for more accurate predictions of phosphorous availability, and water content in Martian rocks; greatly strengthening efforts to constrain when and how the ingredients for life on Mars, and potentially throughout the Solar System may have existed.

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Further investigation of the relationship between population density, unsewered waste input, and As in Bangladesh groundwaters

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Over 40 million Bangladeshi rely on groundwater with arsenic (As) concentrations often exceeding the Bangladesh water quality guideline. Previous research at two high-population sites in Araihazar, Bangladesh suggests human/animal waste is an important source of young organic carbon supporting microbial communities in As-bearing aquifers. This study assesses the relationships between population density, local sewage input, and aquifer microbial abundance using microbial biomarkers to ascertain their impacts on arsenic release. Aquifer matrix cores were collected at two additional sites in Araihazar, Desert Island (DI) which has light grey reduced Holocene sediments bearing high As concentrations (37-188 µg/L) and Doper Tek (DT) with oxidized orange clay-rich Pleistocene sediment bearing low As concentrations (avg 7 µg/L). Low population site DI is hypothesized to receive low sewage inputs whereas high population site DT is hypothesized to receive greater sewage inputs. Estimated cell abundances were generally higher at DI than DT. Similar estimated cell abundances were observed at DT and previous sites suggesting comparable community sizes in the oxidized DT sediments. In contrast, estimated cell abundances were higher at DI suggesting elevated microbial activity. Detection of coprostanol suggests inputs of unsewered waste are occurring at both DI and DT. Although the Sewage Contamination Index indicated sewage was not the dominant source of sterols at either site, unsewered waste appears to be a more important component of the overall organic sterol pool at DT (high population) than DI (low population).

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Microbial communities supported by Precambrian fracture water in the deep subsurface

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The deep terrestrial subsurface is known to harbor microbial life at depths of up to several kilometers where, in some cases, organisms live independently from the photosphere and atmosphere. Ancient fracture fluids trapped within the crystalline basement of the Canadian Precambrian Shield have been shown to be preserved on geologic timescales (millions to billions of years). To characterize the microbial communities associated with fracture fluids from Kidd Creek Mine in Timmins, ON, large volumes of water from two boreholes, 12261 and 12299, were passively filtered for 6-12 months to collect microbial biomass.

Membrane component phospholipid fatty acids (PLFA) representative of viable microbial cells were extracted and analyzed by GC - MS and GC - IRMS. Abundant PLFA were present in all samples, indicating the presence of extant microbial communities. The geochemistry of the porewaters from each borehole were similar and are thought to be sourced from the same fracture system. However, while PLFA distributions were identical between replicates of each borehole, they were distinct between boreholes suggesting differences in the microbial communities detected. Individual PLFA biomarkers indicate the presence of sulphate-reducing bacteria associated with 12261, consistent with recent MPN results for this borehole, but this marker was absent from 12299. Carbon isotope analysis of lipids for 12261 shows heavier δ13C values for all PLFA, which was not observed for 12299, indicating the utilization of different metabolic pathways. Currently it is not known whether this difference is representative of microbial communities living within the fracture system, or a result of differential growth of communities within the filters over their deployment. Understanding the structure and function of microbial communities associated with fracture waters in Precambrian rock environments has the potential to provide new insights into the capabilities, limits and evolution of life.

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Assessment of the relationship between the biodegradation of hydrocarbons and the production of methane in an oil sands End Pit Lake

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Efforts are underway to develop effective methods to manage tailings and reclaim land impacted by extraction of the Alberta oil sands. Syncrude Canada Ltd. has undertaken the first full scale demonstration of water-capped Fluid Fine Tailings (FFT) via the development of Base Mine Lake (BML), an end pit lake (EPL) commissioned in 2012. A key component of this reclamation technology is the maintenance of an oxic water column which is required for establishment of a functioning ecosystem within the lake. However, the oxidation of dissolved methane released from the underlying tailings can reduce dissolved oxygen levels in the water column and impede EPL function. Methane is produced primarily via fermentation of organic residues within the tailings. Understanding the character, abundance, and variability of these organics will enable assessment of methane generation potential from the tailings and inform future management decisions. In this study, fluid fine tailings (FFT) samples were collected from 2 depths at 3 locations, and two time points from BML. These samples were extracted, fractionated, then analyzed using multidimensional gas chromatography (GC-GC) in order to resolve the individual compound families that could have the greatest role in methane generation. GCGC based analysis showed that the primary group of compounds present in the FFT are well resolved groups of alkylated aromatics, branched and cyclic branched alkanes in addition to steranes and hopanes. Ongoing research will further assess the distribution patterns and variability of these compounds in order to determine their biodegradation potential and role in methane generation.

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Tracing mercury sources in contaminated freshwater sediments and biota using mercury isotopes: St. Clair River Area of Concern

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Mercury (Hg) in contaminated aquatic ecosystems and its incorporation into food web are an important source of Hg to humans and wildlife. Hg enters aquatic ecosystems from multiple sources including local point sources, terrestrial runoff, and direct atmospheric deposition, and it is not always clear what pools of Hg within an ecosystem are impacting biota. In systems with contaminated sediments, traditional methods explore the relationship between the sediments and biota by measuring Hg concentrations. However, evaluating the sources of overall Hg burden in biota is challenging and even with extensive Hg concentration data, it is often still not clear what pools of Hg are entering the food web.

Hg isotopes have the potential to delineate sources of Hg to sediments and biota, and were used in this study to assess the sources of elevated Hg in sediments and whether the sediments were the source of Hg in local biota in St. Clair River, an Area of Concern (AOC) between the United States and Canada. St. Clair river was designated as an AOC in 1985 due to elevated Hg resulting from years of waste water discharge from numerous industries. Hg concentrations and isotope compositions in sediments, plankton and zebra mussels were measured along the river both upstream and downstream of known sources. Upstream and downstream sediments and biota were found to be isotopically distinct from each other. In sediments, a unique, very negative δ^{202}Hg signature (-2.41‰) was observed where Hg concentrations were also highest in the sediments, which was near the point of discharge of a chlor-alkali plant that was shut down over ten years ago. Most sediments downstream of this point fell within the range of that negative isotopic signature and also had elevated Hg concentrations, with the exception of two sites located near tributaries. This pinpoints the major source of Hg in the sediments and indicates that Hg isotopes can trace legacy pollution. Plankton and zebra mussels also displayed different isotopic compositions downstream of the point source, and the δ^{202}Hg values between mussels and sediments were strongly linearly correlated. This suggests that the contaminated sediments are a primary source of Hg to the aquatic food web. Overall, this study demonstrates that Hg isotopes can be used to prove that Hg pollution from a historic source was still responsible for current day elevated Hg in sediments, and that Hg from the contaminated sediments are still entering the food web.

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Tracking Atmospheric Mercury Sources by Isotopic Fingerprinting

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Stable mercury (Hg) isotopes are useful tools for tracing mercury in the environment and have recently been applied to trace atmospheric Hg emission sources. However, the application of stable isotopes to trace different emission sources relies on the ability to collect sufficient amount of Hg for isotopic analysis without artifacts. The most common methods for atmospheric Hg collection are through active pumping methods and are generally limited by long pumping times, the potential for passivation/contamination during sampling and the need for a continuous power. Recently a passive air sampler (PAS) for gaseous elemental Hg (GEM) concentrations was developed. One month of sampling by PAS is adequate to collect Hg for isotope analysis. Laboratory and field experiments were conducted to test the PAS ability for isotopic characterization, including controlled temperature experiments (-10 to 30oC) to test the effect of temperature on isotopic fractionation during sampling. Experiments confirm that sampling with this PAS, which involves GEM diffusing through a barrier and adsorbing to carbon, does not result in mass independent fractionation (MIF). However, a consistently observed mass dependent fractionation (MDF) offset of -1 ‰ in δ^{202}Hg is likely related to adsorption of Hg to the carbon. In this study A consistent offset of ~1 ‰ in the MDF was observed at temperatures ranging from 5 to 30oC. A larger MDF offset was observed in the one colder experiment (-10 oC) and needs to be further explored. Above 5oC the MDF offset of the PAS is consistent and correctable and MIF is not affected, and therefore the PAS can be used for both MIF and MDF characterization of GEM. To test this, the PAS was deployed across 57 sites across Ontario and 8 sites in the United States. The results of the experiments and field deployment will be discussed.

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What can we learn about the Arctic from Pb isotopes in seawater?

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The pervasiveness of anthropogenic Pb in the environment and in many remote places is well documented except notably in Arctic seawater. In particular, based on proxy data, it has been suggested that Canadian Arctic waters are pristine and mostly unaffected by anthropogenic Pb. In this study, different sources of dissolved Pb in Canadian Arctic seawater and the above conclusion was tested by measuring Pb isotope ratios of dissolved Pb in seawater samples. Contrary to the conclusions based on proxies, our results show that water column Pb is mostly anthropogenic Pb in the Canada Basin and the other parts of the Canadian Arctic waters are influenced by anthropogenic Pb as well. One surprising finding is the presence of Pb with the lowest 206Pb/207Pb ratios and highest Pb concentrations at some depths that most likely was from 20th century European Pb input providing a snapshot of historical contamination in the Arctic. Even though anthropogenic Pb was pervasive in Arctic seawater, natural Pb was also detected in some parts of the Arctic. Due to the generally low Pb concentrations, the Pb isotope ratios are very sensitive and wide in range reflecting the various Pb sources. Consequently, Pb concentrations and isotopes in the Arctic are useful gauge of the extent of perturbation in the Arctic. Moreover, Pb isotopes will continue to be useful as the sources of Pb to the region could potentially change with increasing human activities (e.g., mining, shipping) and changing natural sources (e.g. permafrost melting) happening.

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AESRC 2019 Keynote Talk
Session 6: Economic Geology and Igneous/Metamorphic Geology
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The search for seafloor hydrothermal vents: Where tectonics, volcanism, and biology meet

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Increasing demand for base and precious metal resources has led to renewed interest in mining on the seafloor. These resources include: manganese (Mn) nodules on sediment-covered abyssal plains, cobalt (Co)-rich crusts on the flanks of seamounts, and seafloor massive sulfides (SMS) associated with hydrothermal venting along tectonic plate boundaries. Mn-nodules and Co-rich crusts offer a vast resource, and mining them may have a profound impact on global metal markets. The resource potential of SMS deposits, however, remains largely unknown due to the lack of information regarding their size, distribution, and composition. In addition, SMS deposits associated with active hydrothermal venting are colonized by unique chemosynthetic ecosystems that should be protected. Despite the strong incentive to explore for inactive vent sites with lower environmental risk, these deposits cannot be detected with current exploration methods that rely on water-column surveys to detect hydrothermal plumes.

Exploration for SMS deposits is driving advances in marine technology, including autonomous underwater vehicles and seafloor lander-type drilling platforms. Geophysical and geochemical data collected at the deposit-scale is integrated with new global datasets, such as satellite altimetry, to provide new insights into the fundamental geodynamic controls on ore formation. This knowledge is critical for developing exploration strategies for finding inactive vent sites that cannot be detected by traditional surveys, and for understanding the diversity of massive sulfide deposits in the geologic record.

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A New Experimental Apparatus to Study Magmatic Process at Precisely Controlled Redox Conditions

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Oxygen fugacity (fO_2) is a fundamental variable affecting phase equilibrium in magmas, and it is typically controlled by using redox buffer assemblages in externally-heated pressure vessel experiments. However, these do not allow fine enough resolution; for example, most arc magmas fall between the fO_2 imposed by the neighboring Ni-NiO and Re-ReO_2 buffers and so does the transition of S^{2-} to S^{6+} in magmas. The Shaw membrane is the most effective technique for measurement and control oxygen fugacity in hydrous experiments in Internally Heated Pressure Vessels (IHPV). Such IHPV are, however, difficult to maintain, consume large amounts of argon and not widely available. Shaw membranes in cold-seal pressure vessels (CSPV) require major design changes to the vessel and the furnace, which we have achieved in our lab. In this work, we present the design of our Shaw membrane for rapid-quench CSPV which is a new design. A custom-made furnace was also built for the setup. Instead of using Ag-Pd alloys, Monel was used as the semi-permeable membrane to control the value of fH_2 in the argon pressure medium which allowed us to significantly extend lifetime and reduce manufacturing cost. For confirmation, a second Shaw membrane was used as a sensor for the hydrogen pressure imposed by the first membrane. Our results show that 95% of the hydrogen pressure imposed was achieved inside the pressure vessel within 3 hours at 900ºC, after which a steady state equilibrium was achieved. Further, Au and Cu solubility in phonolite melts and Fe-Mg partitioning between olivine and melt were used as proof of concept experiments to verify the fO_2 imposed.

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Geological evolution of the Chicobi basin, Quebec: A U-Pb study of intrusive gabbro and syenite in the Malartic transect, Abitibi Greenstone Belt

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The Abitibi Greenstone Belt is one of the most prolific precious and base metal producing regions in the world. Many of the gold deposits and prospects are localized in structurally-bound occurrences within major east trending faults across the terrane, principally the Cadillac-Larder Lake Fault Zone (CLLFZ) and Porcupine-Destor Fault Zone (PDFZ). The Abitibi Subprovince consists of numerous volcanic sequences locally overlain, unconformably, by sedimentary basins. Previous studies have demonstrated that gold bearing faults tend to coincide with deformation events forming these basins, namely those synchronous with late syntectonic activity and ca. 2676-2670 Ma Timiskaming basin formation. This project aims to provide high-precision ID-TIMS U-Pb constraints for crosscutting intrusive rocks through the Chicobi sedimentary basin, ca. 50 km north of the large gold producing Porcupine-Destor (Northern Manneville) Fault Zone in Québec. The study area is located within the Chicobi domain – the northernmost lithotectonic domain of Metal Earth's Malartic transect – comprising mafic volcanic rocks of the Desboues Fm, Lac Arthur and Bearn groups, and sedimentary rocks of the Chicobi basin, which include foliated turbiditic mudstone and sandstone, minor iron formation and conglomerate. A large syenite intrusion (Gemini-Saint-Eloi pluton) and gabbroic dykes crosscut the basin and the surrounding volcanics; high-resolution U-Pb dating of these units will provide absolute ages for magmatic emplacement and constrain the timing of deformational fabric development in this critically understudied region. Moreover, establishing a minimum age for Chicobi basin formation will be diagnostic for regional basin correlations (e.g. Porcupine- (2690-2685 Ma) or Timiskaming-type).

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AESRC 2019 Oral Presentation
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Initial fertility of continental arc magmas

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Porphyry-type deposits are major contributors to the global supply of Cu, Mo, Ag, and Au. These deposits are genetically linked to convergent margins wherein fluid exsolution in shallow magma reservoirs transports ore metals upwards to the site of ore formation in the overlying crust. Although the ore deposits themselves have been extensively studied, the origins of the parental ore-forming magmas are less clear, including the conditions surrounding mantle melting and contributions from subduction-derived fluxing agents. Our current understanding is largely informed by whole rock analyses and samples from oceanic settings. To advance our knowledge of the fertility of continental arc magmas, we sampled several volcanos along a segment of the Andean Southern Volcanic Zone. The northern end of this segment is characterized by intermediate-felsic magmas, thick crust, and some of the world's largest porphyry Cu deposits. Conversely, the southern end is characterized by basaltic magmas, thin crust, and is devoid of porphyry Cu deposits. We determine the composition of glass pockets, originally trapped as droplets of silicate melt by growing phenocrysts. From these, we provide a detailed examination of the concentrations of ore metals, S, and Cl through a continental arc segment, and provide context for factors affecting the variability of magmatic fertility.

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AESRC 2019 Keynote Talk
Session 7: Paleontology
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Complexity in the Oldest Animal Ecosystems

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The Ediacaran Period (635-541 Ma) captures a fundamental stage in the evolution of life. Following the breakup of the Supercontinent Rodinia, the termination of the Marinoan "Snowball" Glaciation, and a discernible increase in the oxygenation of the oceans, the Earth transitioned from a world dominated by microscopic bacteria into one shaped by animal interactions. Marking this transition are the Ediacara biota, a temporally restricted (570-539 Ma), globally distributed group of large, soft-bodied, morphologically complex multicellular organisms. The biological affinities of these creatures are contested, and their extinction prior to the emergence of complex animals is also perplexing. I will combine numerical methods and advanced instrumentation with experimental procedures and field work into a single research program targeting two fundamental questions: 1) How complex were the oldest animal ecosystems? and 2) to what extent is preservation biasing the fossil record of early life?

AESRC 2019 Oral Presentation
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Olfactory Bulb Variation in New World Leaf Nosed Bats

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New World leaf nosed bats (Phyllostomids) are a diverse family of bat with members exhibiting many specialized skull morphologies to accommodate a variety of diets, including frugivory, insectivory, nectarivory, and hematophagy. This diversity of foraging ecology makes Phyllostomids ideal for studies of comparative morphology and neuroanatomy. The goal of this project is to assess the influence of diet on the evolution of the Phyllostomid brain, with a focus on variations in the olfactory bulbs between clades with different diets. Fourteen species were chosen to represent the 12 subfamilies of Phyllostomidae, a distantly related species of herbivorous bat (Pteropodidae) and a closely related outgroup (Mormoopidae). The skulls of each species were borrowed from the mammalogy collection at the Smithsonian Natural History Museum and transported to Vanderbilt University for micro CT scanning. The scans are currently being used to generate endocasts, digital models of the endocranial space which accurately represent the size and shape of the brain. Accurate linear and volumetric measurements of the olfactory bulbs and brain can be gathered from these models for comparison between the selected species. By examining the variations of the olfactory bulb in Phyllostomids we will better understand how different diets influence the evolution of the brain. These methods can then be applied to fossil bats, as the construction of digital endocasts is often used to accurately analyze the brain morphology of prehistoric animals.

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Early Neoproterozoic macrofossils from the Wernecke Mountains, Yukon

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The Tonian (1000 to 720 Ma) represents a critical transition in Earth history between the Mesoproterozoic (1600 Ga to 1000 Ma) and the low latitude glaciations of the Cryogenian (720 to 635 Ma). However, the early Tonian period is notoriously poorly understood and well-preserved exposures are rare in the stratigraphic record. The Proterozoic inliers of Yukon present an opportunity to more accurately characterize the environmental conditions of the early Tonian and extract information on biospheric evolution at this time. Previously undocumented Tonian macrofossils were discovered in the ca. 900 Ma Dolores Creek Formation of the Wernecke Mountains during fieldwork in July 2018. The Dolores Creek Formation is the oldest formation of the basal Hematite Creek Group, which forms the base of the Mackenzie Mountain Supergroup in eastern Yukon. The Dolores Creek Formation in this studied location consists of dark grey to black siltstone with minor orange-weathering stromatolitic intervals. Ninety samples were recovered from seven macrofossil-bearing horizons in an ~1km-thick section of the Dolores Creek Formation near the headwaters of Hematite Creek. The macrofossils have a filamentous structure and comprise repeated segments. There are clear taphonomic differences in the sampled specimens ranging from exceptionally preserved specimens with three-dimensional preservation to poorly preserved specimens that do not display clear segmentation. Analytical microscopy techniques will be used to the investigate structure and taphonomy of the macrofossils discovered in the Dolores Creek Formation to provide insight into their origin and phylogeny. Molecular clock analyses estimate that several key eukaryotic lineages evolved and began to diversify during the Tonian. These well-preserved macrofossils present a unique opportunity to add valuable paleontological data and gain insight into this crucial time period in Earth's biospheric evolution.

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Investigating feeding strategies and fluid dynamics of irregular archaeocyathans from the Forteau Formation, Southern Labrador, Canada

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Today, corals are the dominant reef producers, but this has not always been the case. During the early Cambrian (530 Ma), one of the earliest animal reef builders, the archaeocyathans, emerged and quickly dominated the ecosystem before declining during the Middile Cambrian and going extinct before the Ordovician. While studying these ancient organisms provides insight into the evolution of filter feeding and ancient reef builders, they more importantly allow us to study reef ecosystems without the corals that dominate our modern oceans. Towards the end of their temporal range, a population of Irregulares archaeocythans were preserved in the pink cliffs of the Forteau Formation located on the coast of the Strait of Bell Isle in southern Labrador. These represent some of the best preserved examples of Cambrian reef mounds in the world. Uniquely, the reef mounds here are almost entirely comprised of a single species of archaeocyathan, Metaldetes profundus, but show a great variety of growth forms ranging from branching sticks to flat plate like. We use 3-dimensional models and computational fluid dynamics (CFD) to explain how fluids moved through these organisms, preliminarily assess why M. profundus shows this great degree of morphologic variation, and explore why this single species dominates the ecosystem.

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Decay experiment analyzing sulfur as a limiting reagent in fossiliferous siderite concretion formation

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Soft-tissue fossil interpretation remains difficult due to an incomplete understanding of how fossil formation occurs. Fossiliferous siderite concretions from Mazon Creek have been theorized to form within the sulfate-reducing zone despite pyrite being the favoured iron mineral. A decay experiment has been designed to test the mechanisms behind siderite precipitation leading to soft-tissue fossilization. Ghost shrimp were decayed within a 3D-printed, sealed enclosure in which environmental conditions are monitored. CO2, H2S, and CH4 concentrations within the headspace of the vessel were monitored to give an indication of when aerobic decay, sulfate-reduction, and methanogenesis initiated, respectively. The system temperature, pH and reducing potential were monitored to determine when the chemistry of the environment favoured pyrite or siderite precipitation. Planned experiments will involve varying the amount of sulfur present in the sediment as it is hypothesized that sulfur exhaustion is the most likely cause of an early transition from sulfate-reduction to methanogenesis. Sediment samples will be removed for mineral analysis at critical moments in the experiment, using pre-installed soil core implements. Preliminary experiments have shown that carbon dioxide gas concentrations are consistent with early aerobic decay leading to anoxia.

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Glaciers as Insight into the Creation and Excavation of the Dolpo Basin, Western Nepal

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The landscape of Western Nepal has been dramatically shaped by tectonics and by both glacial and fluvial erosion. Here we investigate the modern geomorphic and glacial features of the Dolpo basin in northern mid-western Nepal. We analyze attributes such as glacier size, slope, aspect and toe, head and peak elevation for 446 glaciers within and around the basin, determining their relationship with basin features such as lithology, slope and precipitation. Glaciers reflect lithology and precipitation, but glacier size is strongly correlated with base-level and slope. Our data suggest that low-slope glaciers with high base-level, i.e., those that flow onto the Tibetan plateau, are forced to grow large because they exist at or above the ELA. Glaciers within the basin, particularly in the western part, can become dismembered on steep slopes, an effect only partly offset by precipitation. The spatial variability in regional slope and presence of a wind gap along the northern basin border suggest recent capture of the Dolpo basin. A plateau-like morphology would have thus once extended at least 45 km southward. The southward opening of the basin allowed precipitation to enter, forming glaciers along the western end of the northern basin border. Larger glaciers (resulting from high base-level) pushed the ridge southward over time through headward erosion. Our study suggests dramatic landscape reorganization in western Nepal, consistent with other recent studies suggesting a more extensive proto-Tibet.

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Exploring the Interaction of Climate, Tectonics, and Glaciers in the Gurla Mandhata Region, Northwest Nepal

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Glacial erosion in the Himalaya is often overlooked as tectonics is regularly seen as the driver of landscape evolution. However, the interaction of climate, tectonic, and glacier systems with one another profoundly shape the landscape over time. In this study, we investigate the relationships among climate, tectonics, and glacier systems in the Gurla Mandhata massif, a gneiss-dome in northeast Nepal, using digital elevation data and analysis in ArcMap 10.4. We delineated 547 glaciers and 408 peaks by hand using user-based decisions and strictly defined criteria. Glaciers and peaks were grouped into North and South clusters and glacial features such as peak elevation, length, and area were measured. With log-based statistical analysis we found a relationship between slope and area along with length, finding that glaciers with a steeper slope are smaller and shorter, while glaciers with a shallow slope are larger and longer. In addition, peak elevation and precipitation are negatively correlated. Within the context of tectonics, lithology is an important factor as the resistance of the underlying rocks comparing North and South clusters can play an active part in landscape dynamics. Overall, this study focuses on the interaction of climate, tectonics, and glaciers in the Gurla Mandhata and contributes to existing knowledge in the Himalaya.

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Attached/semi-attached lithospheric drips and their surface expression with insights from analogue modelling

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Lithospheric drips may develop at the lowermost portion of the mantle lithosphere (colder/denser mantle lithosphere) and sink into the underlying sub-lithospheric mantle. Inferred mainly from a series of geological and geophysical interpretations (i.e., surface subsidence, uplift, and shortening) this process is responsible for the removal or thinning of the lithosphere in intraplate (e.g. North China Craton) and active orogenic regions (e.g. Cordilleran magmatic arcs, Anatolia). Previous studies focused on the surface impacts of the dripping mantle lithosphere and were mainly in a 2D geometry. In this study, we have conducted a series of scaled 3D analogue/laboratory experiments with quantitative analyses using the high-resolution Particle Image Velocimetry (PIV) technique. We explore how the attachment of a lithospheric drip to the upper part of the mantle lithosphere evolves, and additionally how the surface crust responds to the deeper lithospheric removal process. The model includes a sub-lithospheric mantle (PDMS), mantle lithosphere (PDMS and plasticine) and upper crust (silica spheres and e-spheres in a plexiglass box. Model results show that a semi-attached lithospheric drip only yields subsidence, with no evidence of shortening; whereas lithospheric drip fully attached to the crust will produce subsidence followed by thickening/shortening of the upper crust. At the later stages of the coupled drip-mantle lithosphere experiments, the drip thins and necks and the surface topography uplifts. In models with a lower viscosity mantle lithosphere opposed to a higher viscosity model, several secondary drips develop in addition to the primary lithospheric downwelling. The models show a variety of tectonic features comparable to areas where lithospheric drips have been postulated on Earth (e.g., circular sedimentary basins that developed distant from plate boundaries).

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Final magnitude and source-station epicentral distance estimation using Autoencoders and Recurrent Neural Networks

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Application of machine learning algorithms to improve (Earthquake Early Warning System) EEWS performance for on-site approach, where a single station is located near a user/target site is the goal of this research.

Final magnitude and source-distance estimation using first 3 seconds of P-phase is presented here and estimation of peak ground motion at the user-site is currently in progress.

To estimate final magnitude, 80186 vertical records (HHZ, EHZ) of P-wave with catalog final magnitude between 3-4.5 from multiple stations were selected and divided into training/validation (78000) and test sets (2186). Subsequently 4 levels of noise were added to extend the size of the training set and increase the model's capability to handle noisy dataset. A total of 390000 traces were used for training/validation of the model with 50 epochs, 5 patience tolerance, and 256 batch size. The best performing model and its weights were used to predict the final magnitude on 2186 traces in test set, and the resulting accuracy is reported at 98.39% with 0.3 error tolerance and 92.23% for 0.2 error tolerance in estimated magnitude.

To estimate the source-station distance, initial dataset consists of 830000 HHZ records of P-wave arrival from multiple stations with source-distance range 0-120 km. For the purpose of training the algorithm one arbitrary station is selected for training and testing (assuming that the station would be an on-site station near the user location).

The model is composed of a pretrained half denoise-autoencoder network composed of 1D convolution layers (where data space is mapped from a 600-dimensional space to 75 dimensions, i.e. reducing the dimensionality of feature space, yet expanding the feature abstraction), stacked dense net, and stacked LSTM neural net. The accuracy report on the unseen 1819 test set is 81% with 5 km error tolerance.

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Source Mechanism Characterization during Hydraulic Fracturing

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The goal of this study is to apply polarity-based ray tracing method for precise source localization and full-waveform moment-tensor methods for robust source mechanism inversions to an industrial microseismic data set provided by our industrial partner. These source location and mechanism results are be then combined with existing geomechanical simulation tools to understand the in-situ stress and its effect on the types of fractures during hydraulic fracturing. After building an appropriate 1D background velocity model (with undulating interfaces) applicable to the hydraulic stimulation region, we apply the Reverse-Time Ray Tracing Method (RTRTM) (Liang Ding et al, 2018) to find source locations based on both surface and borehole array data. More complex velocity model can be further incorporated by considering seismic anisotropy. After appropriate source location identification, moment-tensor inversion is performed to obtain the best possible source mechanism by minimizing an objective function that quantifies the waveform difference between data and synthetics with possible time shifts allowed to accommodate unmodelled 3D heterogeneities. Furthermore, forward geomechanical simulation using finite-discrete element methods (F/DEM) is performed. Results of moment tensor inversion from microseismic data are compared with fractures from geomechanical simulation to explore the effect of in-situ stress to fracture patterns. For example, we can first start with the regional stress regime given by the World Stress Map to check if the acquired mechanisms are consistent and geologically meaningful. Any discrepancy between these two sources of results can be used to fine-tune local in-situ stress and help us explore the controlling factors in generating a Discrete Fracture Networks (DFN) to efficiently drain the unconventional reservoir.

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Seismic imaging of the lithosphere of Alaska using ambient noise adjoint tomography

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Alaska is one of the most tectonically active regions in the world. Its high seismic and volcanic activities are closely related to the unique tectonic feature: (1) it marks the "corner" where the ocean-continent collision gradually transforms into normal subduction, and (2) it is influenced both by convergent and transform plate boundary. To understand these tectonic processes, it is crucial to study the lithospheric structure in this area. Recent deployment of USArray (IRIS Transportable Array, 2003) in Alaska provides an ideal distribution of seismic stations, which offers an unprecedented opportunity for conducting high-resolution seismic imaging. We use the vertical component of the 2-year long continuous ambient noise signal collected by the ~300 seismic stations in Alaska. The data are processed following the standard procedure (Bensen et al. 2007), and traditional surface wave tomography is conducted to construct a S-velocity model of the lithosphere (0-70km) of Alaska. Moreover, we use the method of adjoint tomography (e.g., Tape et al. 2007) to refine the model. Since adjoint method takes into account heterogeneity and the finite-frequency effect, we are able improve the resolution of our model.

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Systematic Complex Permittivity Measurements of Ilmenite-bearing Lunar Analogue Materials

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Earth-based, orbital, and ground radar systems in addition to microwave radiometers have all been used or are being used on the Moon to study its subsurface structure and composition. Despite an abundance of data, the lack of information on the complex relative permittivity ($\varepsilon_r^* = \varepsilon_r' - i\varepsilon_r''$) and therefore the loss tangent ($\tan\delta = \varepsilon_r''/\varepsilon_r'$) of the surface regolith (lunar soil) and near-surface materials hinders detailed quantitative analysis of lunar radar data. Such analysis includes determining the precise depth of radar-detected subsurface features as well as refining estimates of the abundance of subsurface materials such as the mineral ilmenite, which is known to attenuate radar and microwave signals. We fill this gap by presenting systematic measurements of the complex relative permittivity of powdered bytownite (a Ca-rich plagioclase feldspar) mixed with increasing amounts of ilmenite. Our measurements are made in vacuum across a broad range of frequencies (430 MHz – 8.5 GHz) and normalized to a bulk density of 1.7 g/cm^3. These systematic measurements of lunar regolith analogue materials provide new insights into the frequency-dependent effects of ilmenite content in a low-loss anorthositic matrix (analogue for lunar highland rocks). We find that the addition of ilmenite to bytownite increases the real part of the permittivity as well as the loss tangent (and therefore the attenuation) and also introduces frequency dispersion (change in permittivity with frequency) to both. Since relationships derived in the past to relate complex permittivity of lunar regolith to bulk density (or porosity) and ilmenite content do not take into account frequency dispersion, these results have implications for the attenuation of radar signals at different frequencies on the Moon.

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Colonization of Shocked Basalts from Vargeão Dome and Vista Alegre: Implications for the Search for Life on Mars

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Meteorite impact events into water-bearing targets, though initially detrimental, can provide an environment for rock/water interactions promoting metabolically relevant chemistry required for early life to assemble. The resulting hydrothermal systems are found on Earth as well as Mars. Based on the biological implication of impact-generated lithologies on Earth, there is reason to believe Mars may have served as a niche for microbial life. The majority of Mars' surface is covered by cratered basaltic rock, different from the dynamic sedimentary rock that covers 75% of the Earth's surface. Of the five confirmed impact structures occurring within hydrothermally altered basaltic targets on Earth, Brazilian craters Vargeão Dome (12.4km diameter) and Vista Alegre (9.5km) are widely accessible yet remain unstudied with regards to biological activity. Through petrography, electron imagery, porosity and micro-X-ray diffraction analysis of the samples collected within the craters, areas of bioalteration (biomass attached) in shocked basalts will be identified for metagenomics (DNA culturing and extractions). The proposed project will be the first investigation of microbial colonization in shocked basaltic targets. Using the collected data, a relationship between biomass and shock level in basalts can be explored. Understanding the efficacy of this substrate as a microbial habitat together with the biological potential of hydrothermal systems is important for life detection missions on Mars and the origin and evolution of life on Earth.

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Stable Isotopes of Carbonates: A Tool in the Search for Life?

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Carbonate minerals have been found as magnesium-iron-calcium carbonates in Martian meteorites, such as Allan Hills (ALH) 840001 and Nakhla (Clayton and Mayeda, 1983; McKay et al., 1996; Romanek et al., 1998; Franchi et al., 1997, 1999), and an understanding of stable isotope signatures within these carbonates may be able to help determine whether these extraterrestrial minerals formed via biogenic or abiogenic processes and can thus provide an important tool in the search for life on Mars.

A comparison of oxygen and carbon isotope ratios of Martian carbonate minerals reported within the literature with those found in both biogenic and abiotic processes on Earth may help elucidate whether the oxygen and carbon isotopes could be used as a potential biomarker for life on other worlds. Carbonates which were synthesized using a passive CO2 degassing method through the dissolution of 5, 15 and 25 mmol sodium bicarbonate (NaHCO3) and calcium chloride dihydrate (CaCl2•2H2O) at 25oC will be used to better define and differentiate biogenic vs. abiogenic processes which affect the isotopic signatures of the Martian carbonate minerals.

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From Your Laundry to the Lake: Blue jeans as a source of anthropogenic microfibers to the aquatic environment

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Originally designed as work-wear in the 17th century, blue (denim) jeans have become a modern fashion staple within the last 70 years with 450 million pairs of jeans sold per year in the US alone. Cotton is the most common material used in the production of denim textiles, including blue jeans. Although cotton fibers are classified as a 'natural' fiber, and therefore assumed to be an environmentally friendly material compared to synthetics, cotton can often contain additives and dyes that could influence their persistence and toxicity in the aquatic environment. During washing, frictional forces can cause the loss of microfibers and chemical additives from cotton materials to outgoing wastewater. Wastewater treatment plants (WWTPs) are known conduits of microfibers to the aquatic environment. We hypothesize (1) blue jeans are a major contributor of cotton microfibers to WWTPs and (2) that WWTP effluent is a conduit for cotton/cellulose microfibers to enter the aquatic environment. To investigate blue jean washing as a source of microfibers to wastewater, we washed triplicate pairs of Levi Strauss & Co. straight-legged, dark-wash blue jeans (98-100% cotton). Three treatments included: new distressed, new, and used jeans. Microfibers were chemically characterized using Raman spectroscopy. Preliminary results show that a single pair of blue jeans shed approximately 2,840 fibers per L, 90% of which were cellulose and/or contained indigo dyes. To determine if WWTP effluent is a conduit for cellulose/cotton fibers to enter the aquatic environment, three replicate 24-h composite samples of final effluent were collected for microplastics and microfiber analysis from two WWTPs in southwestern Ontario. Approximately 80% of particles in the effluent samples were microfibers with 70% of the microfibers consisting of cellulose and/or indigo dyes. The chemical make-up of fibers found in WWTP effluent corresponds with those released from washing blue jeans, indicating blue jeans may be a source of microfibers to the aquatic environment. Our results indicate that approximately 0.7 - 5.7 billion cellulosic microfibers per day are discharged to Lake Ontario via each sampled WWTP.

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Geochemical analyses of barite associated with polymetallic ore deposits, Cyclades District, Greece

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In the Cycladic islands of Greece, polymetallic ore deposits occur in an extensional back-arc setting due to the subduction of Africa beneath Europe. Most of the polymetallic ore deposits are Miocene and younger, and associated with barite mineralization. For this project barite samples were taken from four localities within the back-arc: carbonate replacement (Lavrion), low to high sulphidation epithermal (Milos) and vein type deposits (Mykonos and Antiparos). Barite is almost always ore-associated and allows to track the source components of the ore forming fluids. Microstructural and petrological analyses, scanning electron microscopy (SEM) imaging and electron microprobe chemical analysis were done on twelve samples from the different localities. Barite crystals are euhedral to subhedral bladed in all samples and large (mm-cm) in size. Ba concentration varies from 56.6-66.0 wt.%, with the widest range from Lavrion and the smallest from Antiparos. Sr concentration varies from 0-5.2 wt.%, with a sample from a high sulphidation deposit on Milos possessing the largest variation; Ca varies from 0-0.4 wt.%, with Mykonos exhibiting the highest values and a bimodal distribution; and Pb from 0-0.6 wt.%, with Lavrion being the only deposit showing a significant dispersion in concentrations. Most samples have Pb concentration below the detection limits, which is in contrast to previously reported values in the literature. SEM images reveal two types of zonations, geometric growth zones and blotchy areas, which is mainly related to the variation in Sr concentration. In addition to sulfide inclusions, fluid inclusions with variable vapour:liquid ratios were observed. The barite varies in composition between deposits, where carbonate replacement in Lavrion shows the widest range in Ba, Ca and Pb concentrations. Petrographic and geochemical studies of ore-associated barite give an insight on the fluid and crustal sources of the different mineral deposits in the Cyclades.

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High-Precision U-Pb Geochronology within Metal Earth's Superior Province Transects: a Progress Report

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Stratigraphic correlation is critical for understanding the development of greenstone belts, and for identifying syngenetic mineralized horizons for exploration models. Within the Abitibi greenstone belt, the intervals that separate significant lithotectonic assemblages or magmatic events are on the order of a million years, requiring high temporal resolution of age measurements to make meaningful stratigraphic correlations. Although Archean zircons present analytical challenges that can reduce measurement accuracy, chemical abrasion isotope dilution thermal ionization mass spectrometry (CA-ID-TIMS) is a robust method that can reliably yield highly precise and accurate age measurements from such grains. Using this method, we have obtained new zircon ages from samples collected from the Chibougamau, Geraldton-Beardmore, and Swayze transects of Metal Earth's 2018 mapping program.

In the Chibougamau transect, new ages collected for the Blondeau Formation suggest rapid eruption of both Cycle 1 and Cycle 2 felsic volcanics of the Roy Group. Zircon fractions analyzed from the Kukatush Hill porphyry in the northern part of the Swayze greenstone belt constrain the age of this successor basin to the Porcupine assemblage. Data presented from a Au-Mo vein-hosting quartz-feldspar porphyry in the Geraldton-Beardmore transect relate the body to a suite of dated porphyries elsewhere in the eastern Wabigoon subprovince and constrain a maximum age for the Humboldt Bay deformation zone. Zircon ages determined in this project contribute to a decades-long body of work establishing the stratigraphy, metal endowment, and development of the Abitibi greenstone belt, and further Metal Earth's goal of understanding Precambrian geodynamic processes and metallogeny.

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The Importance of Pyrite in Soft-Bodied Fossilization in Mazon Creek, Illinois

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Fern fossils found in Mazon Creek were found to be fossilized in a siderite environment dating back to the Pennsylvania-Moscovian period. During the process of decay, these ferns are encased in a siderite casing, and the anerobic environment allows for pyrite to precipitate. Pyrite, pyritizes faster than the rate of decay preserving organisms exceptionally as “three-dimensional” fossils. If this proves to be accurate, the three-dimensional fossils will contain pyrite, and the poorer quality two-dimensional fossils should contain no pyrite. In order to conduct this analysis several three-dimensional and two-dimensional fossils were selected and analyzed under a scanning electron micoscope for electron feedback compositional imaging. The higher quality fossil between the two, the three-dimensional fossils contained sulfur an indicator of pyrite which protects and preserves the fossil in exceptional detail. The lower quality two-dimensional fossil did not contain any sulfur. Instead of pyrite, this fossil contained aluminosilicates, which preserve anatomical structures poorly. Together, these results support the hypothesis that the higher quality fossils will contain pyrite.

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