AESRC 2017

ADVANCES IN EARTH SCIENCE RESEARCH CONFERENCE

MARCH 31- APRIL 2

CONFERENCE PACKAGE

AESRC 2017

A letter from the 2017 Organizing Committee

Welcome to AESRC 2017 at the University of Western Ontario! We are so glad to have you, and are especially grateful to those who travelled far to come to London, Ontario. This conference has been successfully bringing together graduate and mature undergraduate students in a wide range of technical sessions, seminars, and poster presentations. We would like to thank Carleton University for organizing a wonderful AESRC last year and we hope that this year's AESRC is equally successful. Finally, we would like to thank our sponsors. These are the organizations that have made it possible for us to organize this annual conference. Together, the sponsors graciously donated $5,000.00 in student prizes. Thank you!

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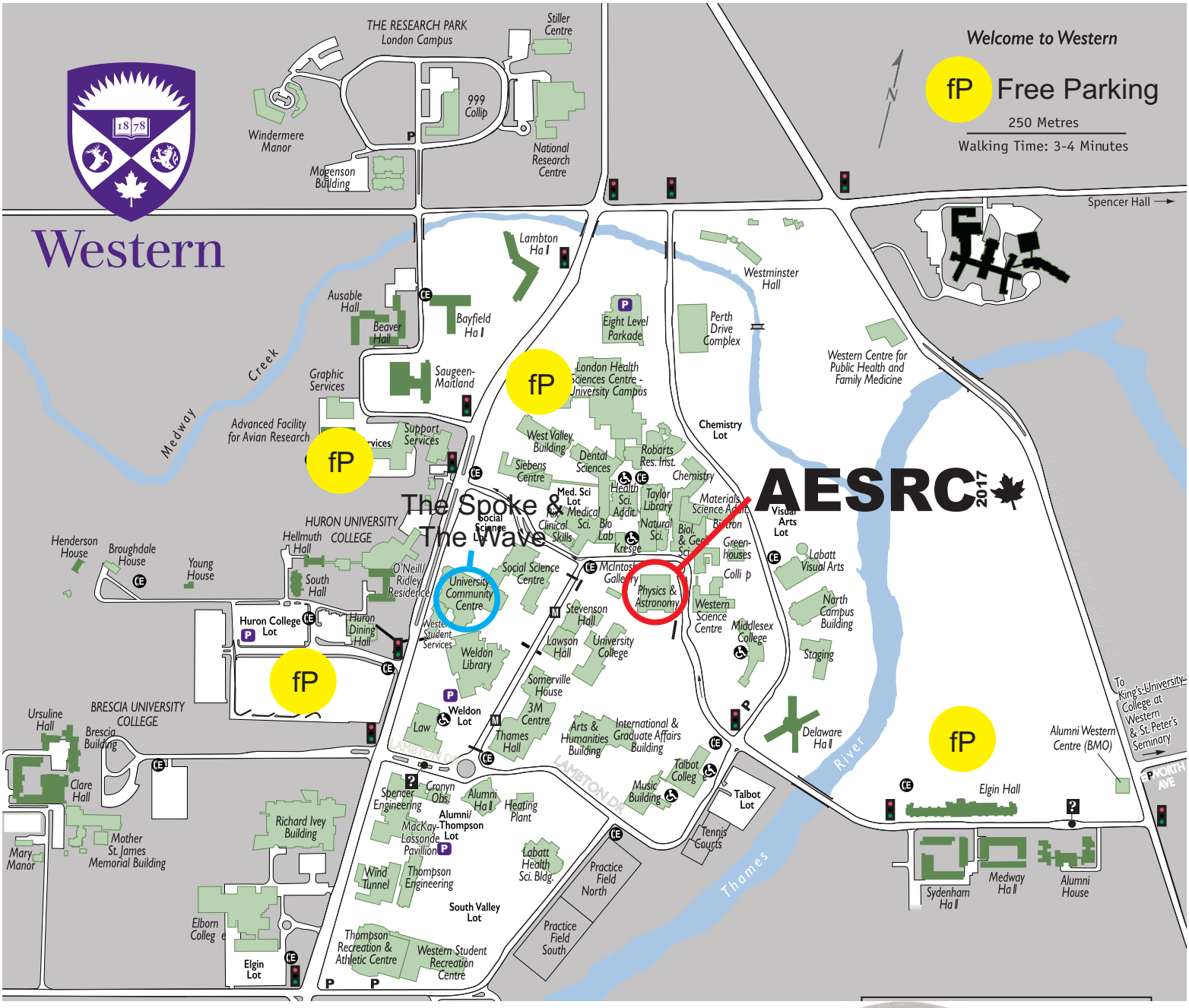

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Physics and Astronomy Atrium and Room 106

March 31, 2016

6:00 – 11:00 PM: **Meet, Greet and Registration at Spoke Café**

April 1, 2016

Note: Keynote Speakers and Technical Session talks will be held in Room 106 in the Physics and Astronomy Building. Poster Sessions will be in the Physics and Astronomy Atrium

8:30 – 9:00 AM: **Registration and Poster Setup in Physics and Astronomy Atrium**

9:00 – 9:15 AM: **Welcome from the AESRC Committee**

9:15 – 10:15 AM: **Technical Session 1: Environmental**

TIME	TITLE	SPEAKER
9:15 – 9:30 AM	ISOTOPIC ANALYSIS OF BLACK CARBON IN CANADIAN ARCTIC AIR	Marianne Luna
9:30 – 9:45 AM	RECONSTRUCTING ARCTIC SEA ICE COVER FROM LONG-LIVED CORALLINE ALGAE	Sarah Shana
9:45 – 10:00 AM	HOLOCENE CARBON BALANCE AND TESTATE AMOEBAE COMMUNITY STRUCTURE IN THE HUDSON BAY LOWLANDS, ONTARIO, CANADA	Marissa Davies
10:00 – 10:15 AM	A CASE STUDY OF HOUSTON, TEXAS: RISK ANALYSIS OF FLOOD EVENTS LED BY HURRICANE STORM SURGE AND EXTREME RAINFALL RUNOFF	Elaine Lu

10:15 – 10:30 AM: **Coffee Break in Physics and Astronomy Atrium**

10:30 AM – 12:00 PM: Technical Session 2: Sedimentary Geology and Paleontology I

TIME	TITLE	SPEAKER
10:30 – 10:45 AM	CLEARING THE MUDDY WATERS: HIGH-RESOLUTION SEDIMENTOLOGICAL ANALYSIS OF MATRIX-RICH SANDSTONE IN THE WINDERMERE TURBIDITE SYSTEM AND COMPARISON WITH EQUIVALENT DEPOSITS FROM OTHER DEEP-MARINE SYSTEMS	Jag Ningthoujam
10:45 – 11:00 AM	INVESTIGATING THE CONTROLS ON THE DISTRIBUTION OF EDIACARAN DEPOSITS AND THE IMPACT ON THEIR MORPHOLOGY IN SOUTHERN NAMIBIA	Katie Maloney
11:00 – 11:15 AM	CONSTRUCTION AND USE OF AN EXPERIMENTAL VESSEL TO INVESTIGATE THE INFLUENCE OF CLAY MINERALOGY ON SOFT-TISSUE DECAY AND PRESERVATION	Amanda Facciol
11:15 – 11:30 AM	SOFT-SEDIMENT DEFORMATION STRUCTURE AND RELATED MICROBIAL MAT STRUCTURES IN GORDON LAKE FORMATION, HURONIAN SUPERGROUP	Carolyn Hill
11:30 – 11:45 AM	SOLVING THE SECOND WHITE SPECKS: INTEGRATING PETROPHYSCS AND ALLOSTRATIGRAPHY TO FIND THE SWEET SPOTS	Kienan Marion
11:45 AM – 12:00 PM	ALLOSTRATIGRAPHIC ANALYSIS OF THE MARINE TO NON-MARINE TRANSITION IN LATE ALBIAN STRAT, SW ALBERTA	Celeste Cunningham

12:00 – 12:45 PM: Lunch in Physics and Astronomy Atrium

12:45 – 1:15 AM: Keynote Speaker

Speaker: Marc Laflamme

Title: "The First Mass-Extinction of Complex Life"

1:15 – 1:45 PM: Technical Session 3: Sedimentary Geology and Paleontology II

TIME	TITLE	SPEAKER
1:15 – 1:30 PM	STABLE ISOTOPES OF ANCIENT BONES AS A PROXY FOR PALEOENVIRONMENT: THE CASE OF LATE PLEISTOCENE MUSKOXEN	Stephanie Mabee
1:30 – 1:45 PM	PALEOENVIRONMENTAL IMPLICATION OF RUGOSE CORAL GROWTH RIDGED IN THE MIDDLE DEVONIAN HUNGRY HOLLOW MEMBER, MICHIGAN BASIN	Andrew Thomson

1:45 – 2:30 PM: Technical Session 4: Posters

2:30 – 3:00 PM: Keynote Speaker

Speaker: Keith Barron

Title: "Exploring for Gold in the Amazon Regions of Ecuador"

3:00 – 3:30 PM: Technical Session 5: Economic Geology Sponsored by the Society of Economic Geologists

TIME	TITLE	SPEAKER
3:00 – 3:15 PM	SYNTHETIC APERTURE RADAR FOR GEOLOGICAL MAPPING SALT DIAPIRS, AXEL HEIBERG ISLAND, NU	Elise Harrington
3:15 – 3:30 PM	PD DEPORTMENT IN THE NO-SEE-UM ZONE OF THE LAC DE ILES COMPLEX, ONTARIO	Yining Wang

3:30 - 4:00 PM: **Technical Session 6: Igneous and Metamorphic Geology and Geochemistry**

TIME	TITLE	SPEAKER
3:30 – 3:45 PM	USE OF ANISOTROPY OF MAGNETIC SUSCEPTIBILITY TO ANALYZE PETRO-FABRICS IN CU AND PGE BEARING GABBROIC UNITS OF THE MARATHON CU-PGE DEPOSIT, ONTARIO	Hiruni Gunawardana
3:45 – 4:00 PM	EXPERIMENTAL CONSTRAINT ON CALCIUM ISOTOPIC FRACTIONATION IN CARBONATED MELTS	Matthew Maloney

7:00 – 11:00 PM: **Conference Dinner**

8:00 - 8:30 PM: Adrian Smith: "Volunteering: More Than a Means to an End A Small-Town Ontarian's Perspective"

8:30 - 9:00 PM: Collin Etienne: "Preparing for the Oil and Gas Industry"

April 2, 2016

8:45 – 9:15 AM: **Keynote Speaker**

Speaker: Robert Shcherbakov

Title: "Physics and Statistics of Aftershocks"

9:15 –10:15 AM: **Technical Session 7: Geophysics I Sponsored by the Solid Earth Section**

TIME	TITLE	SPEAKER
9:15– 9:30 AM	VIBRATION MONITORING AT WIND TURBINE SITE IN PORT ALMA	Melanie Postman
9:30 – 9:45 AM	BEST STRATEGIES AND PRACTICES FOR EARTHQUAKE SITE CHARACTERIZATION AT ONTARIO BRIDGE SITES	Alex Bilson Darko
9:45 – 10:00 AM	INVESTIGATION OF THE IMPACT OF PRE-EXISTING FRACTURES IN ENHANCES RESERVOIR TREATMENTS	Hongyuan Zhou
10:00 – 10:15 AM	FRACTURE PROPAGATION CHARACTERISTICS AND MICROMECHANISMS ANALYSIS OF UNCONVENTIONAL RESERVOIRS SANDSTONE USING ACIDIZING PROCESS AND INDENTATION EXPERIMENT	Jinghan Zhong

10:15 - 10:30 AM: **Coffee Break in Physics and Astronomy Atrium**

10:30 –11:15 AM: **Technical Session 8: Geophysics II Sponsored by the Solid Earth Section**

TIME	TITLE	SPEAKER
10:30 – 10:45 PM	FOLD SEGMENT LINKAGE AND UPLIFT RATES ALONG THE JANAURI AND CHANDIGARH ANTICLINES, NORTHWESTERN INDIA	Evelyn Moorhouse
10:45– 11:00 PM	FINITE/DISCRETE ELEMENT MODELING OF TUNNEL STABILITY IN SWELLING SHALY GROUND	Yusheng Qiu
11:00 – 11:15 PM	DEEP EARTHQUAKES IN THE LAB: DETECTION OF ACOUSTIC ACTIVITY DUE TO TRANSFORMATIONAL FAULTING ASSOCIATED WITH THE OLIVINE TO SPINEL TRANSFORMATION IN FAYALITE	Timothy Officer

11:15 AM – 12:00 PM: **Technical Session 9: Posters**

12:00 – 1:00 PM: **Lunch in Physics and Astronomy Atrium**

AESRC Annual General Meeting in Room 106 in the Physics and Astronomy Building

1:00 – 1:30 PM: **Keynote Speaker**

Speaker: Phil McCausland

Title: "X-ray Micro CT Imaging of Meteorites: A New Frontier in Non-Destructive 3D Sample Analysis"

1:30 – 2:00 PM: Technical Session 10: Planetary

TIME	TITLE	SPEAKER
1:30 – 1:45 PM	PIECES OF THE PLANET BUILDING PUZZLE: CHARACTERIZATION OF EARLY SOLAR SYSTEM MELT ENVIRONMENTS RECORDED IN THE UREILITE, LONDRANITE-ACAPULOCOITE AND METACHONDRITE METEORITE GROUPS	Brendt Hyde
1:45 – 2:00 PM	OPTICAL MATURITY AND ROCK ABUNDANCE: DATING THE LUNAR SURFACE WITH REMOTE SENSING	Christian Udovicic

2:00 – 2:30 PM: Break in Physics and Astronomy Atrium

2:30 – 2:45 PM: Awards in Physics and Astronomy Atrium

Poster Presentations

Location	TITLE	Presenter
A	EVALUATION AND CLASSIFICATION OF AN UNTYPED ORDINARY CHONDRITE	Stephen Korchinos
B	CLASSIFICATION OF AN UNIDENTIFIED ORDINARY CHONDRITE	Tanya Kizovski and Caroline Lee
C	SPACE ROCKS ROCK! CLASSIFYING NEW METEORITE IN THE ROM'S COLLECTION	Jenny Li
D	CATION ORDERING IN SPINEL FROM CALCIUM ALUMINUM INCLUSIONS IN CARBONACEOUS CHONDRITES TO QUANTIFY TEMPERATURE IN THE EARLY SOLAR NEBULA	Victoria Houde
E	THE CONTRIBUTION OF UNCERTAINTY IN MAGNITUDE AND LOCATION TO NEAR-DISTANCE VARIABILITY IN GROUND MOTIONS FOR POTENTIALLY-INDUCED EARTHQUAKES IN OKLAHOMA	Joanna Holmgren
F	APPLYING BINARY FORECASTING APPROACHES TO INDUCED SEISMICITY IN THE WESTERN CANADA SEDIMENTARY BASIN	Ryan Kahue
G	THE ROLE OF NON-INVASIVE AMBIENT NOISE ANALYSIS IN IMPROVING SEISMIC MICROZONTATION MAPPING IN VANCOUVER, BRITISH COLUMBIA, CANADA	Frederick Jackson
H	CHARACTERIZATION OF EARTHQUAKE SITE AMPLIFICATION IN ALBERTA, CANADA	Joseph Farrugia
I	QUANTIFICATION OF SHOCK STAGES IN UREILITE OLIVINE IN NWA 221 BY INSITU MICRO-X-RAY DIFFRACTION	Yaozhu Li
J	AGE AND PETROLOGY OF POSSIBLE GRENVILLE-AGE CRUSTAL XENOLITHS FROM KIMBERLITE IN EASTERN KENTUCKY	Richard Chow
K	P-T-X CONSTRAINTS ON ILMENITE UNIT CELL AND RELATIONSHIP TO DIAMOND POTENTIAL IN KIMBERLITES	Mitchell Galarneau
L	THE RELATIONSHIP BETWEEN PYRITE BEARING VEINS AND GOLD WITHIN THE CANADIAN MALARTIC FOOTPRINT	Neera Sundaralingam
M	FINE FRACTION INDICATOR MINERAL SIGNATURES OF PORPHYRY, VMS AND OTHER DEPOSITS	Donald Lougheed
N	CARBONATE ISOTOPES OF SHELLY FAUNA DESCRIBE LATE-PLEISTOCENE-HOLOCENE DEPOSITIONAL ENVIRONMENT IN THE HURON BASIN, ONTARIO, CANADA	Jane Wilson
O	REGIONAL DISTRIBUTION AND SPATIAL PATTERNS OF RECENT SHALLOW WATER BENTHIC FORAMINIFERA FROM PUNTA CHIVATO, GULF OF CALIFORNIA MEXICO	Melanie Delago Brand
P	BENTHIC FORAMINIFERA ASSEMBLAGES FROM ISLA SAN JOSE, GULF OF CALIFORNIA MEXICO	Cedelle Pereira
Q	LAUNCHING YOUR RESEARCH: INTERNATIONAL FIELD STUDY EXPERIENCE IN SAN SALVADOR, THE BAHAMAS	Johnathan Davidson
R	INFLUENCE OF THE PRESENCE OF GAS PHASE ON THE ROCK DEFORMATION PROCESSES: A NUMERICAL STUDY	Hongyuan Zhou and Yusheng Qiu on behalf of Olga Kovaleva

AESRC 2017 ABSTRACTS

Technical Session 1: Environmental

ISOTOPIC ANALYSIS OF BLACK CARBON IN CANADIAN ARCTIC AIR

Lahaie Luna Marianne, Cornett Jack, Crann Carley, Zhao Xiaolei

Black carbon is a significant greenhouse gas, which contributes to climate change and in high enough concentrations can cause detrimental effects to human health. The purpose of the study is to determine the dominant source of black carbon in Canada's Arctic air in order to obtain a better understanding of its origins and to aid in the creation of policies to better regulate their emissions. Samples of black carbon from Canada's Arctic were analysed using filter paper in order to evaluate the origin of the black carbon. To determine whether its source is anthropogenic or natural, the C^{14} content was evaluated. C^{14} is produced during natural combustions of biomass and is not present during the combustion of petrochemical substances. Therefore, the filter papers were combusted at different temperatures, their gasses collected and then graphitized in order to properly determine their isotopic components. The results for the analysis will be further discussed.

RECONSTRUCTING ARCTIC SEA ICE COVER FROM LONG-LIVED CORALLINE ALGAE

Shana, Sarah[1], Halfar, Jochen[1], Tsay, Sasha[2], Zajacz, Zoltan[2]

[1] Department of Chemical and Physical Sciences, University of Toronto at Mississauga, 3359 Mississauga Rd. N, Mississauga, ON, L5L 1C6, Canada

[2] Department of Earth Sciences, University of Toronto, 22 Russell Street, Toronto, ON, M5S 3B1, Canada

Arctic climate has been warming significantly in the past few decades and that has led to decreased sea ice coverage at an unprecedented rate. With less than 40 years of data, available satellite records do not shed light on long term variability in sea ice, therefore to correctly understand long-term behaviour of sea ice, we need to obtain ice data from past centuries. A good way to achieve this is by using proxies that are able to preserve long history records. The only marine proxy known today for reconstructing century-scale Arctic sea-ice variability at annual resolution is shallow benthic coralline algae of the genus *Clathromorphum*. *Clathromorphum* is found across the Arctic Ocean and exhibits a long life-span of up to 650 years while depositing annual growth bands in a calcified structure. Growth increment widths in this photosynthesizing organism are strongly dependent on light availability on the shallow seafloor, and has been shown to be related to sea ice duration, where low growth rates are indicative or long duration sea-ice cover. For this study, we analyzed 16 specimens of *Clathromorphum* collected from Rigby Bay, northern Lancaster Sound, Nunavut, Canada in

summer 2016 and subsequently polished and imaged. Since growth increments were not easily identifiable using optical methods, one specimen was analyzed using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry for Mg/Ca ratio composition in line transects along the direction of growth. Mg/Ca ratios in *Clathromorphum* exhibit annual cyclicities, and cycles can therefore be related to growth increment widths. The established growth age model indicates that the specimen has grown continuously since 1860. Comparing growth increment widths to satellite-derived summer (July to October) sea-ice concentration at the collection site since 1979 shows a tight negative relationship ($r= 0.5947$, $p< 0.001$, $n=37$). Spatial correlations with satellite-derived sea ice concentration across the Canadian Arctic Archipelago indicate highest correlations in the northern Lancaster Sound region, confirming the suitability of this specimen for sea ice reconstructions. The reconstruction prior to satellite observations shows an overall sea ice decline since the mid 19th century. However, long-term variability is indicated by periods of low sea-ice cover in from the 1930s to 1940s followed by high sea-ice cover from the 1950s to 1970s. In summary, the time series shows that sea ice decline has been ongoing at least since the beginning of the industrial revolution, while exhibiting its steepest and ongoing decline starting in the 1970s.

HOLOCENE CARBON BALANCE AND TESTATE AMOEBAE COMMUNITY STRUCTURE IN THE HUDSON BAY LOWLANDS, ONTARIO, CANADA

Davies, Marissa A. and Finkelstein, Sarah A.

Department of Earth Sciences, University of Toronto, 22 Russell St., Toronto, Ontario, Canada, M56 3B1

Peatlands are an important component of the global carbon cycle as they are a net carbon sink and store a third of the terrestrial soil carbon pool. They also are an important source of methane to the atmosphere and it remains uncertain what the net balance of carbon fluxes from these ecosystems will be with future warming. Holocene paleoecological records allow for the investigation of long-term changes in peatlands, but the relative role of autogenic and allogenic factors can make interpretations difficult. Therefore, a multi-proxy approach is needed. The Hudson Bay Lowlands (HBL), a vast continuous peatland surrounding the Hudson and James Bay regions, and has accumulated large stores of carbon during the Holocene and previous non-glacial intervals. Recent work has shown that climate, succession, isostatic uplift, and hydrology all influence carbon accumulation and peatland development in the HBL, but limited work has been done to understand their influence on Holocene carbon balance. The proposed research aims to investigate the role of hydrologic, vegetation, and climatic changes on carbon balance in peatlands across the Holocene Epoch by utilizing a multi-proxy approach. Peat cores will be taken from the southwestern HBL and peat carbon content will be determined and combined with geochronological data to model carbon uptake and release over time. Modelled carbon fluxes will be compared to proxy-based reconstructions of vegetation, water table depth, and air temperature. A novel biomarker proxy derived from bacterial membrane lipids (branched glycerol dialkyl glycerol tetraethers), will be calibrated to determine its utility in obtaining a local Holocene temperature record. Testate amoebae, protists that are sensitive to water table and pH changes, will be used to produce quantitative estimates of water table fluctuations using a regional transfer function and will improve the interpretation of the biomarker records, which are influenced by hydrologic changes. Functional groups of testate

amoebae, which assign species to environmentally-influenced trait types, will also be used to identify changes in community structure and food web dynamics with varying paleoenvironmental conditions. Plant macrofossils will be identified in conjunction with testate amoebae to detect vegetation changes. By using a multi-proxy approach to understand the role of climate in the HBL, this will allow us to better predict the region's response to future climatic changes. Furthermore, potential linkages between changing carbon balance and testate amoebae functional group assemblages may help to better understand peatland carbon pathways.

A CASE STUDY OF HOUSTON, TEXAS: RISK ANALYSIS OF FLOOD EVENTS LED BY: HURRICANE STORM SURGE & EXTREME RAINFALL RUN-OFF

Lu Xueya(XL)

Risk Prediction Initiative, Bermuda Institution of Ocean Science

Hurricanes are often accompanied by a rise in sea level and heavy rainfall which can result in serious flooding events along coastal cities with high exposure. Little research has emphasized the correlation between flooding, hurricane storm surge and heavy rainfall run-off during real events for enhancing effective flood risk migration. The purpose of the study is to create a practical methodology on the topic and provide informative ideas for future studies in the related field. In this regard, a case study in Houston Texas is conducted to examine the flood variability caused by hurricane storm surge and extreme precipitation. Return period calculation for storm surge level and statistical analyses on tide gauge observations, precipitation and ENSO: MEI data were also performed to determine various trends or variability. The study calculated a flooding threshold storm surge level of 0.3420m for small areas of beach erosion with a return period of 2.6 years using hurricane data within 130 kilometers (70 nautical miles) around Houston. MEI for ENSO showed certain influence on the annual total precipitation amount and a running correlation between annual precipitation level and ENSO by decades was also discovered. Although trying to relate the local flood events and extreme rainfall-run off is rather challenging due to complex hydrological and geographical factors, the risk brought by extreme rainfall events is estimated by calculating the return periods for annual extreme precipitation events around Houston using extreme value theory in statistical analysis.

Technical Session 2 and 3: Sedimentary Geology and Paleontology

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CLEARING THE MUDDY WATERS: HIGH-RESOLUTION SEDIMENTOLOGICAL ANALYSIS OF MATRIX-RICH SANDSTONE IN THE WINDERMERE TURBIDITE SYSTEM AND COMPARISON WITH EQUIVALENT DEPOSITS FROM OTHER DEEP-MARINE SYSTEMS.

Ningthoujam Jagabir (NJ)

Department of Earth Sciences and Ottawa-Carleton Geosciences Centre, University of Ottawa, 140 Louis Pasteur Pvt., Ottawa, ON K1N 6N5, Canada, jning027@uottawa.ca.

The description, classification, and origin of deep-marine matrix-rich sandstones (i.e. sandstone with significant (> 10%) mud matrix) have been debated since the 18th century when the term greywacke was introduced in the geological literature. Sedimentologists have generally attempted to either define them based on their texture and/or composition or origin of their matrix (detrital vs. diagenetic). However, in the last decade, it has been increasingly recognized that there exists a variety of matrix-rich strata that are unlike classical turbidites or debrites and should be examined and interpreted based on their formative mechanisms and associated depositional environments. Currently, deep-water matrix-rich beds are generally categorized as slurry beds or linked debrites/hybrid-event beds deposits. Slurry beds are typically a few cm to over 30m thick with a distinctive intercalation of finer- and coarser-grained sediment layers. Matrix ranges from 10-35% matrix and syndepositional fluid expulsion features are common. Linked debrites/hybrid event bedsets are typically several dm thick with a basal matrix-poor turbidite (fine- to medium-grained) overlain sharply by a matrix-rich (~20%) debrite (very fine- to fine-grained) with abundant clasts of various sizes and lithologies, and common liquefaction-related structures and sand injection. Both types of matrix-rich beds are interpreted to be deposited by flows that underwent a longitudinal change to a more cohesive behaviour and form deposits that extend over few km's to 100's km in the medial to distal parts of submarine fans.

In the Neoproterozoic Windermere Supergroup, matrix-rich sandstones are characteristically flat-based, a few cm- to several dm-thick, fine- to medium-grained, with matrix content ranging from 10 to 70%, although typically 30-50%. Significantly, beds lack a basal clean sandstone or evidence of dewatering, and locally contain few cm-long mudstone clasts oriented parallel to bedding. Moreover, beds extend for only a few to several 100s m laterally and in slope to medial basin floor settings, and are interpreted to represent the initiation of the local sedimentary system in response to a local upflow avulsion.

The discrepancy between matrix-rich sandstones from the Windermere turbidite system compared to other deep-marine matrix-rich sandy strata is striking. The objective of this study, therefore, is to more fully document matrix-rich sandstones in the Windermere Supergroup, and then develop a comprehensive list of criteria to help discriminate the spectrum of matrix-rich sandstone facies, their physical origin, and ultimately their interpretative significance.

INVESTIGATING THE CONTROLS ON THE DISTRIBUTION OF EDIACARAN DEPOSITS AND THE IMPACT ON THEIR MORPHOLOGY IN SOUTHERN NAMIBIA

Maloney, Katie M. [1], Facciol, Amanda J. [1], Gibson, Brandt M. [2], Cribb, Alison[2], Koester, Bryce E. [2], Racicot, Rachel A.,[3] Darroch, Simon A.F. [2], and Laflamme, Marc[1]

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The latest Neoproterozoic (Ediacaran: 635–541 Ma) is a crucial period of Earth history because it represents the emergence of the oldest known large complex, multicellular organisms, the Ediacara Biota. These organisms have a worldwide distribution and have been documented to straddle the Ediacaran-Cambrian boundary in Namibia.

The Nama Group of southern Namibia hosts abundant and diverse Ediacaran fossils; these fossils were deposited in a foreland basin associated with the Damara Orogen during the assembly of Gondwana (580 to 680 Ma). The Kuibis Subgroup in the southern subbasin is of particular interest because it hosts an abundance of *Ernietta*, a classic Ediacaran fossil, characterized by a sac-shaped body and walls constructed from two parallel tabular tubes. To gain valuable insight into the paleoecology of the Ediacara biota, a detailed facies analysis was conducted focusing on the Kaines Member of the Kuibis Subgroup. Our fieldwork at Farm Hansberg resulted in the collection of more than 240 *Ernietta* specimens from 10 distinct horizons at 6 sites. A thorough facies analysis of these sections was conducted and all specimens of *Ernietta* were photographed and their morphology quantified. The resulting database was analyzed using the package MCLUST R to investigate the life habit and growth of the individual organisms with respect to different facies. Our facies analysis will aid in determining how each paleoenvironment affected the population of *Ernietta* in terms of size distribution, abundance, and taphonomic grade. The emphasis on integrating both sedimentary and paleontological data into a single study of Ediacaran population dynamics will provide valuable insight into ecosystem development at the dawn of animal life.

CONSTRUCTION AND USE OF AN EXPERIMENTAL VESSEL TO INVESTIGATE THE INFLUENCE OF CLAY MINERALOGY ON SOFT-TISSUE DECAY AND PRESERVATION

Facciol, Amanda, Piunno, Paul, Laflamme, Marc.

University of Toronto Mississauga, Department of Chemical and Physical Sciences

The processes underlying soft-tissue fossilization remain poorly understood. Softer tissues, such as hair or muscle, are less likely to be preserved, creating a bias toward the preservation of hard parts such as teeth, bones, and shells. Modern taphonomic research focuses on monitoring the geobiochemical changes that occur during tissue decay, as these processes are highly dependent on environmental conditions and microbial interactions that occur soon after death. The most significant parameters to monitor during decay leading to soft-tissue preservation include: 1) production of volatiles, such as carbon dioxide and hydrogen sulfide, 2) changes in aqueous pH and 3) changes in sediment mineralization. To this end, a gas and water tight vessel was constructed to allow for continuous monitoring of decay environments. The complement of sensors can be altered to monitor any aspect of decay product production, however for the purposes of this study, it was equipped with a CO_2 sensor, a pH meter, and three sediment core extraction implements. Data logging of all sensor responses was done continuously by use of a dedicated Arduino microcontroller. The sampling schedule for sediment core analysis can be set to any desired interval. In this study, the vessel was used to examine the influence of clay mineralogy on the decay of a model organism (Shrimp – *Penaeus monodon*). Sediments were selected to target different mineralogies,

including aluminum-rich clay, iron-rich clay, and clay of varying mineralogy. Preliminary results have shown that presence of clay alone influences the rate of CO_2 production and pH alternation compared to experiments done using silica sand, where kaolinite clay allows for faster CO_2 release and earlier pH changes. This decay vessel has permitted for detailed analysis of fossilization processes under laboratory timescales. This in turn will help to elucidate preservational biases within the fossil record and provide clues as to why certain geologic periods, such as the Cambrian or Ediacaran, have higher instances of soft-tissue fossilization.

SOFT-SEDIMENT DEFORMATION STRUCTURES AND RELATED MICROBIAL MAT STRUCTURES IN THE GORDON LAKE FORMATION, HURONIAN SUPERGROUP

Hill, C.M., and Corcoran, P.L.

Department of Earth Sciences, The University of Western Ontario, 1151 Richmond St. N., London, ON, N6A 5B7, chill59@uwo.ca

Well preserved soft-sediment deformation structures (SSDS) were recognized in the Gordon Lake Formation of the ca. 2.45-2.22 Ga Paleoproterozoic Huronian Supergroup in the Bruce Mines area, Ontario. One 37 m thick outcrop exposure composed of mudstone to medium-grained sandstone contains various types of load casts, flame structures, convolute bedding, and ball and pillow structures that range in size from 1 to 120 cm. *In situ m*icrobial mat structures and mat chips up to 100 cm long were identified in one 6 m thick interval of the outcrop. The relationship between a number of the SSDS and microbial mat structures suggests that ancient biofilms formed impermeable barriers that impeded water escape, which led to overpressuring and subsequent soft-sediment deformation. Deposition of the Gordon Lake Formation in a tidally-influenced, shallow marine environment is supported by the presence of desiccation cracks, lenticular bedding, microbial mats, SSDS, and the gradational contact with the overlying tidal channel-sand shoal deposits of the Bar River Formation. Based on the depositional environment and sedimentological characteristics of the succession, in addition to the recurrence of SSDS, overpressuring and loading by storm waves are interpreted to have led to the formation of the SSDS. In general, SSDS are infrequent and smaller in outcrops of the Gordon Lake Formation in the Flack Lake, Baie Fine, and Cobalt plains area, which suggests that the western portion of the basin may have been affected by different sedimentary processes or local tectonic events.

SOLVING THE SECOND WHITE SPECKS: INTEGRATING PETROPHYSICS AND ALLOSTRATIGRAPHY TO FIND SWEET SPOTS

Marion, K.P., Cheadle, B.A.; Western University

The Upper Cretaceous Second White Specks Formation, a thin-bedded heterogeneous mudrock succession within the Lower Colorado allogroup, is a prolific self-sourcing tight oil reservoir within the Western Canada Foreland Basin (WCFB) in Alberta. Despite significant production (>1 MMBbl) from certain wells, unpredictable inflow performance has prevented it from being established as a resource play. Developing a fracture prediction method for the Second

White Specks is essential for sweet spotting, as its producibility depends upon intersecting natural fracture networks.

Focused in a 110-township area in west-central Alberta, this study demonstrated the predictive capacity of mappable petrophysical attributes (i.e.: porosity, organic richness, brittleness, mineralogy) for locating areas with enhanced oil production potential in the Second White Specks tight oil play. This study evaluates the relative contributions of mappable petrophysical properties to fluid inflow performance in the Second White Specks by developing an integrated petrophysical and stratigraphic workflow, which could be applied to other analogous mudrock intervals. The Second White Specks tight oil play lends itself well to an integrated study, due to its anisotropic nature and fracture dependency. By placing the petrophysical properties of the Second White Specks into an allostratigraphic framework, areas with enhanced depositional porosity and increased fracture intensity may be more easily located, potentially allowing for better well placement.

Conventional core analyses are rare in the Second White Specks because the zone has not been a primary exploration target. In order to develop a robust lithological model of the Second White Specks Formation, detailed mineralogical analyses are required in order to ground-truth petrophysically-derived mineralogy. We performed x-ray fluorescence (XRF) of framework and clay minerals on a suite of samples from five cores in the study area. A multiple linear regression model was developed in order to determine the strength of statistical correlation between specific petrophysical logs and mineral content, which were then used to build a petrophysically-derived mineral model for the study area.

The mineral model revealed regional mineralogical variations that correlated to increased oil production when constrained to coeval depositional units within a high-resolution allostratigraphic framework. This mineral model is calibrated to core control, and is a first approximation of relative brittle behaviour of the Second White Specks and Belle Fourche alloformations. This study may prove invaluable for locating prospective zones that are naturally fractured. This research has regional application across the WCFB, and could be applied to mudstone formations in other basins where core analysis is sparse.

ALLOSTRATIGRAPHIC ANALYSIS OF THE MARINE TO NONMARINE TRANSITION IN LATE ALBIAN STRATA, SW ALBERTA

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Late Albian rocks are distributed across much of central and southern Alberta and are dominated by transgressive marine mudstone of the Joli Fou Formation, overlain by regressive shallow-marine sandstone of the Viking Formation. In SW Alberta, Joli Fou and Viking facies pass laterally south- and westward into marginal-marine and coastal plain sediments of the Bow Island Formation (subsurface) and equivalent Mill Creek Formation (Foothills outcrop). Although the marine Joli Fou and Viking strata have been partitioned into genetic allomembers on the basis of regional marine flooding surfaces, these bounding surfaces have not been systematically traced into marginal- and non-marine deposits of the Bow Island and Mill Creek formations. In this study, six major disconformable surfaces were correlated through a grid of 10

cross-sections encompassing 241 wireline well logs distributed over 4,500 km^2. The correlations show that marginal-marine deposits equivalent to the Joli Fou alloformation thin to the west and north, and pinch out completely against underlying Mannville Group rocks. Joli Fou strata thicken dramatically to the south of township 15 along a lineament that is co-linear with the Vulcan Structure that separates two Archean basement blocks. The overlying Viking alloformation thins across the Vulcan Structure, suggesting the sense of differential subsidence was reversed from Joli Fou to Viking time. In the NE, the Viking alloformation consists of well-defined, sandier-upward marine packages that, to the SW, pass laterally into 'spiky' wireline log facies indicative of coastal plain deposits. Isolith maps of Viking sandstones reveal a series of lobate sandbodies, interpreted as deltas that built eastward into the basin, fed by fluvial systems draining the adjacent Cordillera. In outcrop, the Mill Creek Formation comprises a basal Lynx Creek Member, about 25 m thick, that forms sandier-upward successions with wave ripples, HCS and a low-diversity ichnofauna, interpreted to represent storm-influenced lakes and bays that formed during the initial transgression of the Joli Fou Sea. The overlying Bruin Creek Member is equivalent to the upper Joli Fou and Viking alloformations. These rocks comprise rubbly, pedogenically-modified sideritic siltstones and rippled and cross-stratified sandstones with interstratified coal and volcanic tuffs; rooted horizons and plant debris are common. Deposition took place on an aggrading coastal plain in response to slow tectonic subsidence. This new allostratigraphic framework allows marine depositional sequences, and implied sea-level changes, to be traced onto the coeval coastal plain, thereby allowing alluvial facies to be more readily interpreted in terms of changing accommodation rate.

STABLE ISOTOPES OF ANCIENT BONES AS A PROXY FOR PALEOENVIRONMENT: THE CASE OF LATE PLEISTOCENE MUSKOXEN

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Stable isotope analyses of mammalian bones and teeth are useful for reconstructing paleoenvironments. Understanding ecosystem dynamics of the past may help us predict future environmental shifts. At the end of the late Pleistocene (11.7ka), approximately 70 species of large mammals that once thrived throughout the Mammoth Steppe biome became extinct. Causes of this extinction are debated, with the most accepted views being climate change and/or human exploitation. The stable isotope compositions of the extant muskox, *Ovibos moschatus*, along with the closely-related extinct muskox *Bootherium bombifrons*, provide paleodietary and paleoenvironmental information about the response of the Mammoth Steppe to climate change. These data for Pleistocene muskoxen may help us infer why *Ovibos* survived extinction, whilst *Bootherium* and many other types of megafauna did not.

Muskox specimens spanning dates of 50ka-9ka ^{14}C ybp have been sampled from Alaska, Yukon Territory, Alberta, Saskatchewan, North Carolina and South Carolina. Preliminary results for stable carbon and nitrogen isotope bone collagen suggest that *Ovibos* occupied a larger ecological niche than *Bootherium*. *Ovibos* appears to have had a more opportunistic diet that included a greater variety of forage types, which also suggests a larger range of habitats. This adaptability may have enabled the survival of *Ovibos* when it was faced with climate and vegetation changes. Understanding late Pleistocene muskox diet and habitat should help us

understand the adaptability of modern muskox populations when faced with environmental changes. Such information can help to direct current and future conservation efforts, and predict the consequences for muskox populations in the Arctic regions, as warming continues to accelerate in these regions.

PALEOENVIRONMENTAL IMPLICATIONS OF RUGOSE CORAL GROWTH RIDGES IN THE MIDDLE DEVONIAN HUNGRY HOLLOW MEMBER, MICHIGAN BASIN

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The fossil skeletons of Paleozoic rugose corals feature micron-scale growth ridges on their outer surface (epitheca) that record the successive positions of the coral polyp during longitudinal corallite growth. Epithecal ridges and intervening troughs represent short-term increases (radial polyp expansion) and decreases (radial polyp constriction) in skeletal accretion. Judging by the utility of modern scleractinian corals as climate proxies, studies on short-term growth cyclicity in rugose ancient coral taxa should have some potential in providing insight on the paleoenvironmental factors that affected biota in ancient marine environments. For purposes of characterizing and quantifying the cyclic characteristics of rugose growth ridges beyond the level of ridge counting, specimens of rugose corals *Eridophyllum* and *Cystiphylloides* from the Hungry Hollow Member of the Middle Devonian Widder Formation were examined. Specimens with well-preserved epitheca were scanned using Micro-CT to preserve a 3D model prior to being cross-sectioned longitudinally (along their growth axis) for closer examination in thin section and backscatter SEM imaging. Image processing and filtering techniques were applied to a stitched mosaic of SEM images of the edge of the coral epitheca to extract a line representing the coral surface. This will allow statistical analysis to be applied to this dataset, to find patterns relevant to possible paleoenvironmental and astronomical cycles. Initial analysis of the images has corroborated previous research; largest-scale ridges contain ~13 smaller bundles, previously interpreted to represent lunar months in the Devonian year. These monthly packages are divided into ~ 30 ridges, believed to represent days for the faster-spinning Earth. Interestingly, these monthly groups seem to be subdivided into two distinct packages of 15 ridges, which may suggest a further connection of rugose coral growth with lunar cycles. As seen with modern corals, there may have been a possible lunar cycle relationship with reproductive cycles and allocation of the organism's resources. Potential challenges with this task include the determinations of a zero-line against which fluctuations in coral growth can be compared and quantified. The superposition of random non-cyclic or semi-cyclic growth factors, such as those recording episodes of storm disturbance (which can also lead to changes in growth direction), climate variation, predation, or turbidity may have modified the growth of the individual, masking the influence of cyclic factors. This research will provide insight into the paleoenvironmental, and possible astronomical factors that affected marine biota of Southwestern Ontario.

Technical Session 4: Posters

EVALUATION AND CLASSIFICATION OF AN UNTYPED ORDINARY CHONDRITE

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The purpose of this study is to classify an unnamed ordinary chondrite meteorite for submission into the Meteoritical Bulletin Database. Thin section microscopy and X-ray powder diffractometer techniques were used to determine the rock's petrologic type, shock stage, weathering classification, and chondrite group. The rock was cut for preparation of the thin section and for analysis by the Brucker D8 Advance X-Ray Powder Diffractometer with copper source. The meteorite is from the Moroccan Saharan desert and has a dark fusion crust with cracks and regmaglypts. Its matrix is aphanitic with light- to dark-brown millimetre-sized chondrules and shows visible signs of terrestrial weathering in the form of limonite-rust. It is classified as petrologic type 6 due to most chondrules having poorly defined boundaries indicating the meteorite has undergone a high degree of thermal metamorphism resulting in solid state recrystallization. Its modal composition is 20% olivine, 30% plagioclase feldspar, 30% clinopyroxene, 15% orthopyroxene, and 5% iron-metal. The sub- to anhedral grains are set in a devitrified matrix and which has largely been replaced by secondary-growth plagioclase feldspar. There are irregular and planar fractures present in many pyroxene, olivine, and plagioclase crystals and undulatory extinction is visible in both pyroxene and olivine crystals indicating shock metamorphism has occurred. In addition, a shock vein is visible both in macro- and microscopic observations. These are typical observations for meteorites with stage 3 shock classification. Limonite rust is visible leaching from metal clasts and within fractures when viewed using a petrographic microscope. The rust has affected between 20-60% of the total metal, thus, the rock shows signs of W2 weathering. Results from the X-Ray diffractometer indicate the meteorite has 2 theta angles of 28.7 and 32.4 for silicon and olivine, respectively. This means it has an Fa number of 24.7 and is a member of the L-chondrite group. Thus, the meteorite is an L6 ordinary chondrite showing signs of S3 metamorphism and W2 terrestrial weathering.

CLASSIFICATION OF AN UNIDENTIFIED ORDINARY CHONDRITE

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In order for meteorites to be used in scientific literature and studied more comprehensively, all unidentified samples must first be classified and a report submitted to the

Meteoritical Society Nomenclature Committee for approval and official recognition. The purpose of this study is to classify an unidentified ordinary chondrite known as sample LM-57439 in the Royal Ontario Museum's collection. LM-57439 is a 55.48 g meteorite that was purchased in Morocco. It's exact find location is unknown but is assumed to be within North West Africa. This sample has been classified as an L4 Type Ordinary Chondrite. In order to complete this classification, the meteorite's petrologic type, shock stage, and weathering grade were determined by examining the sample in thin section and hand sample. Powder X-ray diffraction was also used to determine LM-57439's fayalite number. LM-57439 contains olivine, pyroxene, sulphides, iron metal, and iron oxides; with readily delineated chondrules comprised of barred olivine, porphyritic olivine, radial pyroxene, and porphyritic pyroxene. Based on the well defined chondrules and fine-grained recrystallized matrix observed in thin section, LM-57439 can be classified as petrologic type 4. The undulose extinction and irregular fractures within the olivine grains indicate that LM-57439 experienced shock pressures of 5 – 10 GPa (shock stage S2). Evidence of terrestrial weathering, including oxidation of approximately 50% of the metal grains, as well as rust staining observed on the hand sample, indicate that LM-57432 can be classified as W2 on the weathering scale. All ordinary chondrites can be differentiated into three groups based on the amount of iron oxide content in the silicates (reported as a fayalite number). These groups include H-chondrites (Fa_{16-20}), L-chondrites (Fa_{22-26}), and LL-chondrites (Fa_{27-32}). Representative whole rock powder (prepared by crushing a small chip of LM-57439 using a mortar and pestle) was analyzed by X-ray diffraction (XRD). The results of the XRD analysis yielded a fayalite number of 22.8 for the sample, as such it has been classified as an L-chondrite. All of this information can be tied together to better understand the degree of thermal metamorphism sample LM-57439 has experienced, and gives us clues about its parent body. This sample will also be examined further using an electron microprobe to confirm this preliminary classification.

SPACE ROCKS ROCK! CLASSIFYING A NEW METEORITE IN THE ROM'S COLLECTION

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Chondrites are some of the most ancient matter known in the solar system being 4.55--4.57 Ga. Ordinary chondrites are a subclass of stony meteorites that contain small spherical objects called chondrules. Chondrules form from collisions between extremely hot planetesimals that created molten droplets in the primary stages of our solar system formation; the molten droplets were then accreted to their parent asteroid bodies. These chondrules are made up of silicate minerals (primarily olivine and pyroxene), iron metal, and a fine matrix that holds it all together. The purpose of this research is to classify chondrite DGR030--16S to help solidify further understanding of chemical and mineral composition of the solar system during its infancy. Discovered in 2016 in Morocco, chondrite DGR030--16S has been classified as an H5--type ordinary chondrite by x--ray diffraction, macroscopic observation, and microscopic analysis at the Royal Ontario Museum laboratories. X--ray diffraction was completed using the

Bruker D8 Advance machine that used a copper source to analyze the chemical composition of meteorites. The Olympus BX53M petrographic microscope was used to examine the petrology of this chondrite. The results demonstrated that the chondrite is an H5--type. The “H” indicates that it contains the highest level of total iron and iron metal, as well as the lowest level of iron oxides out of the ordinary chondrite subtype classes. The “5” is a petrologic number indicating that the distinguishing features and chondrule character is visibly less distinct. In addition, the chondrite does not have any shock veins nor a pronounced fusion crust. It also appears that metamorphism has resulted in the recrystallization of silicate compounds in the matrix, likely due to extremely high temperatures on its parent asteroid. Petrogaphic analysis concludes that the chondrite has a W1 weathering stage and a S1 shock stage, indicating little weathering and induration of a low shock pressure (GPa) to its parent asteroid body. The overall chondrite is dominated by >50% of chondrules with five different chondrule textures present. They are largely olivine dominated, which corresponds with the chondrite classification being an H--type with a very high iron content. Implications for future research on DGR030--16S is to use the chronometer method of radioisotope dating to find its absolute age. Figuring out the chondrite’s absolute age would help to confirm or further expand current knowledge of chondrites and its chemical isotope composition.

CATION ORDERING IN SPINEL FROM CALCIUM ALUMINUM INCLUSIONS IN CARBONACEOUS CHONDRITES TO QUANTIFY TEMPERATURE IN THE EARLY SOLAR NEBULA

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The aim of this project is to use spinel found in Calcium Aluminum Inclusions (CAIs) to quantify temperature in the early solar nebula. CAIs, considered the oldest materials in the solar system, are refractory inclusions which commonly occur in carbonaceous chondrites (CCs). The early timing of formation of these CAIs will enable information about the early solar nebula to be inferred.

The mineral spinel ($MgAl_2O_4$) is commonly found in these refractory inclusions. Spinel has a cubic structure of O^{2-} ions with tetrahedral [4] and octahedral [6] voids in which there are Mg^{2+} and Al^{3+} cations respectively. Disorder in spinel is characterized by the inversion parameter (x), described by $^{[4]}(Mg_{1-x}Al_x)^{[6]}[Al_{2-x}Mg_x]O_4$. Formation temperature of spinel is related to x. Disorder can be measured and the formation temperature or temperature of the latest equilibrium can be inferred.

At least three primitive CC meteorites (Allende CV3, Tagish Lake C2, and Paris CM) will be examined for spinel-containing CAIs, which will be identified by micro X-ray diffraction. The spinel of Paris CM is relatively unaltered and the Tagish Lake C2 spinel is only aqueously altered. The unaltered nature of the samples means spinel temperatures will apply to the early solar nebula as opposed to parent body processes, as high temperature alteration can change the cation distribution of minerals. Allende spinel, which has been altered by parent body processes, will be useful for comparison.

Spinel will be separated from CAIs using heavy liquid density separation using refractory index oils and a microcentrifuge. 27-Aluminum Nuclear Magnetic Resonance (NMR)

Spectroscopy will be used to measure the cation order-disorder, which will allow the calculation of x and subsequently the formation temperature of spinel can be inferred.

Currently, temperatures in the early solar system are poorly constrained. Observations of planetary disks around other stars show that age is not the only factor contributing to disk evolution and that the environment within the disk may play a role. This means disk environment could ultimately impact planet formation. Much of the temperature information for CAI formation is inferred. This project will add to the current understanding of the early solar system by providing quantitative temperature information which can be used to develop a history of thermal evolution in the early solar system.

THE CONTRIBUTION OF UNCERTAINTY IN MAGNITUDE AND LOCATION TO NEAR-DISTANCE VARIABILITY IN GROUND MOTIONS FOR POTENTIALLY-INDUCED EARTHQUAKES IN OKLAHOMA

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An important issue in ground motion and hazard analysis for induced earthquakes is the variability of ground-motion amplitudes (referred to as sigma) at close distances (<10 km). We investigate the contributions of errors in magnitude and location to sigma, at <10km, using ground-motion recordings from 55 induced earthquakes in Oklahoma with moment magnitudes between 3.0-4.1. We optimize the location and magnitude of events with respect to a selected ground-motion prediction equation (GMPE) that has zero-bias on average. We define the ground-motion center (the GMC) as the location and magnitude that results in the lowest standard deviation (sigma) with respect to the GMPE. An iterative grid search technique is used to find each event's GMC, alternating between searching for the optimum epicenter of the GMPE and then searching for the optimum moment magnitude; the best location and magnitude is that which minimizes the residuals (averaged over response spectra at 0.5, 1, 3.3, 10 Hz, peak ground acceleration and peak ground velocity). For observations within 10 km, the value of sigma is very sensitive to location, and slightly sensitive to magnitude. Location error impacts the intra-event component of sigma, whereas the magnitude impacts the inter-event component of sigma. Before optimizing the location and magnitude of the events, the total sigma (averaged over the selected frequencies) is 0.28 log10 units, whereas the corresponding sigma value based on the GMC locations and magnitudes is 0.23 log10 units. The results indicate that about 0.05 log10 units of sigma could be attributable to typical errors in location and magnitude, for events in Oklahoma recorded at <10 km.

APPLYING BINARY FORECASTING APPROACHES TO INDUCED SEISMICITY IN THE WESTERN CANADA SEDIMENTARY BASIN

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The Western Canada Sedimentary Basin has been chosen as a focus due to an increase in the recent observed seismicity there which is most likely linked to anthropogenic activities related to unconventional oil and gas exploration. Seismicity caused by these types of activities is called induced seismicity. The occurrence of moderate to larger induced earthquakes in areas where critical infrastructure is present can be potentially problematic. Here we use a binary forecast method to analyze past seismicity and well production data in order to quantify future areas of increased seismicity. The first method utilizes the cumulative Benioff strain. The second method utilizes the cumulative well production data within each bin. In the resulting analysis the hit rate and false alarm rate are determined after optimizing and modifying the initial parameters. It is found that when modifying the cell size and threshold magnitude parameters within various training periods, hit and false alarm rates are obtained for specific regions in Western Canada using both recent seismicity and cumulative well production data. Certain areas are thus shown to be more prone to potential larger earthquakes based on both datasets. This has implications for the potential link between oil and gas production and induced seismicity observed in the Western Canada Sedimentary Basin.

THE ROLE OF NON-INVASIVE AMBIENT NOISE ANALYSIS IN IMPROVING SEISMIC MICROZONATION MAPPING IN VANCOUVER, BRITISH COLUMBIA, CANADA

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Sheri Molnar, Assistant Professor at Western University

There is renewed interest in improving seismic microzonation mapping in Vancouver, British Columbia (BC), the highest seismic risk city in Canada. To highlight the suitability of emerging non-invasive seismic array techniques to regional seismic hazard assessment, we apply them to key high-risk locations in south-western British Columbia. The motivation of this study is to allow the assessment of amplification potential for applications such as engineering analysis and ground motion modelling. Few shear-wave velocity (v_s) measurements in Greater Vancouver are freely available in published literature; this study is a notable contribution to public earthquake site assessments in the area.

We first investigate seismic amplification due to local geology as the cause of varying peak ground acceleration (PGA) in the region from the 2015 M 4.7 Vancouver Island earthquake. We perform single station techniques to analyse the ground motions at strong-motion stations within ~85 km of the epicenter. We show that the spatial distribution of amplification generally agrees with the current regional seismic microzonation map, but with notable exceptions. High amplification is observed on both thick sediment sites and on the northern edge of the Fraser Delta, where the sediment thickness may be favourable to amplify the dominant frequencies, as observed for previous earthquakes.

We then perform passive array-based seismic measurements at 10 high-priority risk schools of the BC school seismic retrofit program primarily in Metro Vancouver, with the aim of investigating v_s profiles. Preliminary dispersion results from array sites are well constrained across all frequencies and are consistent between processing schemes. Joint inversion of resulting dispersion estimates and horizontal-to-vertical (H/V) spectral ratios provides one-dimensional shear wave velocity depth profiles for earthquake site classification.

CHARACTERIZATION OF EARTHQUAKE SITE AMPLIFICATION IN ALBERTA, CANADA

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A marked increase in seismic activity related to oil and gas development in Alberta, Canada over the past decade has highlighted interest in quantifying earthquake ground shaking hazard in the province. In this study, we use horizontal-to-vertical spectral ratios ($HVSR$s) calculated from earthquake ($\overline{eHVSR}$s) and microtremor ($\overline{mHVSR}$s) recordings to establish three empirical models for site amplification at seismic stations in Alberta based on the site surficial geology. Two of the amplification functions are developed for general soil and muskeg (very soft soil) ground conditions; these functions depend on the frequency of maximum amplification, which is either derived directly from a curve fitted to seismic station $HVSR$s (f_{peak}), or indirectly using an estimate for depth-to-bedrock (sediment thickness). The third amplification function is developed for general rock site conditions and has a fixed dependence on frequency. We observe that softer ground conditions are characteristic of larger amplification ratios.

Another significant finding from this study is that $HVSR$s derived from the rapid low-cost microtremor survey method can be used to provide a valid measure of earthquake site amplification in Alberta's geologic setting. Lastly, we find that for sites for which shallow V_S profile information is available, theoretical amplification ratios calculated from composite shear-wave velocity (V_S) profiles are largely consistent with inferences based on empirical $\overline{eHVSR}$s. This provides support for the utility of site-specific V_S profiling.

THE TECTONOMORPHIC ANALYSIS ON THE GULF OF CORINTH (BOEOTIA, GREECE) USING THE VALLEYMORPH TOOL

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Understanding the geomorphic development of a tectonically active landscape can help better assess seismic hazards. One such earthquake prone region is the tectonically active rift in the easternmost extension of the Gulf of Corinth in Boeotia, Greece. The conventional tectonomorphic analysis of a geographical region consists of tedious manual extraction of the Transverse topographic symmetry (T)-factor ratio which determines basin tilt and differential uplift due to tectonic activity. Hence, researchers depend on visual approximations of aerial photographs and satellite imagery on a limited number of watersheds therefore subjectively performing statistical analyses to determine the T-factor values. The ValleyMorph Tool is a Python-based ArcGIS extension presented by Dr. Heidi Daxberger in response to these traditional methods of basin analysis. This automated alternative claims to effectively extract tectonomorphic indices through manipulation of Digital Elevation Models. This study is aimed to study the adaptability, efficiency and accuracy of the ValleyMorph Tool through its application on the tectonically active region in the Gulf of Corinth, Greece. The T-factor results produced in this research were presented in asymmetry vector maps and polar plots. When compared with manually extracted results from a previous study, the asymmetry vectors maps showed a

positive correlation whereas the polar plots displayed no correlation. Possible recommendations and further research opportunities are mentioned in this research.

QUANTIFICATION OF SHOCK STAGES IN UREILITE OLIVINE IN NWA 2221 BY *IN SITU* MICRO-X-RAY DIFFRACTION

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Ureilites are coarse-grained ultramafic primitive achondrite meteorites. They have characteristics that include both chondritic meteorite bulk chemistry (e.g. high siderophile element abundance) and evidence of common planetary differentiation processes (e.g. igneous mineral assemblages and textures). Current classification of shock degree for ureitlites is based on qualitative descriptions of petrographic observations, such as mineral assemblages, textures and extinction of mineral grains. This study uses non-destructive *in situ* micro X-ray diffraction (μXRD) to study the shock stages of ureilite samples. It provides a method for *in situ* examination of rock samples with a range of surfaces, from irregular fractures to cut surfaces and polished thin sections or probe mounts. This study used the BrukerTM D8 Discover μXRD at Western University with a Cu Kα X-ray source (λ = 1.5418 Å) and General Area Detector Diffraction System (GADDS) which obtains 2D diffraction patterns similar to Debye-Scherrer film. Strained minerals exhibit streaks in these diffraction patterns on GADDS images, which lie along the arc of Debye rings, or chi direction (χ) for each lattice plane with Miller index (hkl). These streaks will be integrated into peak-shaped plot, and full width half maximum in chi direction (FWHMχ) will be measured for quantitative study of shock. The data are useful in combination with contextual petrographic observations. Examined sample, Ureilite NWA 2221, consists mostly of olivine and pyroxene with a high abundance of carbon phases, e.g. graphite, lying between olivine and pyroxene grains. It also has abundant metals appearing interstitially to the dominant silicates. Petrographic observation showed that it has typical ureilite triple junction textures formed by granular olivine and pyroxene. Undulose extinction has also been observed in some olivine and pyroxene grains, indicating a mild to moderate shock history as an effect from impacting process. GADDS images for NWA 2221 show streaks, and the possible reason for such peaks can be strain-related mosaicity, or misorientation of subdomains or ‘mosaic blocks’ in a single crystal due to non-uniform strain. Complex and asymmetrical peaks are common in this sample, hence it requires a possible method when measuring FWHMχ for these peaks. The overall objectives of this study are to derive a systematic shock classification specifically for ureilites, and to further examine possible relationships between shock features and ureilite petrogenesis. This study also investigates a solution regarding the overlapping diffraction peaks problem by using multiple orders of Lorentzian function.

AGE AND PETROLOGY OF POSSIBLE GRENVILLE-AGE CRUSTAL XENOLITHS FROM KIMBERLITE IN EASTERN KENTUCKY

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Three kimberlite bodies in Eastern Kentucky contain xenoliths of rocks derived from the crust and upper mantle. As the basement in this region is buried under approximately 2-5km of sedimentary rocks of the Appalachian basin in this study, we have used the crustal xenoliths to provide an insight into the composition of the basement rock and to determine whether or not the crustal xenoliths are a part of the Grenville orogenic belt. To achieve this, petrographic observations, microprobe analysis, and U-Pb dating of the crustal xenoliths has been used to compare and contrast observations, particularly ages and equilibration temperatures, with that of the well preserved and studied Grenville equivalents.

Crustal xenoliths in this study have include garnet granulite, amphibolite, hornblende gabbro/diorite, syenite, gabbro, alkali granite, and andesite. Temperatures of equilibration of an amphibolite, using the amphibole-plagioclase thermometer assuming 10kbars pressure, are approximately 820-880°C for the primary assemblage and 780-815°C for a retrograde assemblage. Temperatures obtained using a garnet-clinopyroxene Fe-Mg exchange thermometer for a garnet granulite are in the range 780-880°C at an assumed pressure of 10kbars. These temperatures agree with that of the Grenville Province equivalents.

Ages of formation of the xenoliths have been determined by dating zircon by the U/Pb method and LA-ICP-MS techniques. One granite yielded an age of ~1055 Ma and an andesite an age of ~1200 Ma. These are equivalent to ages of exposed Grenville crust. An amphibolite was dated at approximately 300 Ma, the age of Alleghanian orogenesis in the southern Appalachians. These preliminary ages can be interpreted as indicating the presence of Grenville basement with an overprint from a younger Appalachian orogenic event.

P-T-X CONSTRAINTS ON ILMENITE UNITE CELL AND RELATIONSHIP TO DIAMONDPOTNENTIALS IN KIMBERLITES

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Exploration companies have utilized indicator minerals in the search for diamond-bearing kimberlites for years. By using the minerals in diamond-bearing rocks, such as kimberlites, the objective is to obtain information that would indicate the possibility of diamonds at a locality. This research focuses on determining any relationships in the mineral ilmenite which correlate particularly with diamonds being present in the rock. This will emphasis on assessing the variation of unit cell structure obtained from non-destructive, micro X-ray diffraction (μXRD) analysis, with that of pressure, temperature, and chemical composition.

Chromites and garnets are within the isometric crystal system, having only one variable parameter, a_o, whereas ilmenites are within the less symmetrical, rhombohedral system, having two variables a_o and c_o. Due to this variability, pressure can allow for compression of the less rigid layers in the structure, which is why it is the main focus for this research. Utilization of various barometers, such as a rutile-ilmenite, chromite-ilmenite, and magnetite-ilmenite barometers, an accurate assessment of the pressure in kimberlitic samples may be obtained. As localities might host multiple minerals and exsolution types, the use of more than one barometer can enable a more reliable pressure measurement.

Chemical composition can be obtained via Electron Probe Microanalysis (EPMA), which will be compared with the unit cell of the ilmenites. Diamond exploration uses the comparison of Mg^{2+} and Ti^{4+} for determining the ilmenites originate from kimberlites, as well as Cr^{2+} to determine if there is a connection between source materials. In theory, these three elements should give the most reliable results when compared with pressure. Furthermore, this will be done for ilmenite samples from both diamondiferous and barren kimberlites to see if the ilmenite crystal structure is correlated with the presence of diamonds in the system.

Obtaining ilmenites from multiple localities around the world, from both diamond-bearing and diamond-barren kimberlites, will enable this research to be more extensive. So far ilmenites have been obtained from the Star (Saskatchewan, Canada), Aultman (Wyoming, U.S.A.), Lake Bullenmerri (Victoria, Australia), Premier (Gauteng, South Africa), Jagersfontein (Free State, South Africa), Bobbejaan (Northern Cape, South Africa), and Udachnaya kimberlite (Sakha Republic, Russia). Kimberlites of both peridotitic and eclogitic compositions are being sought for this research, to seek an understanding of the ilmenite crystal structure variation as a function of host rock type.

THE RELATIONSHIP BETWEEN PYRITE-BEARING VEINS AND GOLD WITHING THE CANADIAN MALARTIC FOOTPRINT

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The main gold mineralization at the Canadian Malartic deposit is associated with disseminated pyrite or fine veinlets, which are related to the D_2 deformation event. The composition of the pyrite within the syn-D_2 veins may therefore record broad-scale fluid circulation, which ultimately may provide evidence for the origin of the deposit. This work focuses on the mineralogical and geochemical analysis of the veins, the pyrite grains within them, and their associated alteration haloes. Over 10 vein generations were recognized within the Canadian Malartic footprint during field work. Only the two main generations that contained pyrite were sampled: one formed early- to syn- D_2 and the other formed syn- to late- D_2. Veins were sampled along two main transects, one trending approximately west from the deposit and the other approximately south from the deposit. 4 groups of primary vein mineralogy can be distinguished from petrographic analyses: group 1: Qz-Ab-Kfs-Bt-Cal, group 2: Qz-Ab-Kfs-Bt, group 3: Qz-Ab-Bt-Cal and group 4: Qz-Bt-Cal. Chlorite is present in nearly all samples and partly replaces biotite. The minor mineral composition of the veins is variable, but may include chalcopyrite, galena, scheelite, molybdenite, barite, rutile, ilmenite, titanite, apatite, muscovite, epidote, REE fluorocarbonate minerals, and zircon. Alteration haloes surrounding the veins are characterized by bands of biotite, disseminated pyrite, and reduced grain size within the host rock. Along the transect to the south, pyrite is increasingly replaced by pyrrhotite, which can be interpreted as a result of the increasing metamorphic grade toward the south. If this interpretation is correct, the implication is that the veins (and possibly a mineralization event) pre-dates metamorphism. Oscillatory zoning was observed within the pyrite grains in maps from electron probe microanalyses, which may reflect fluid mixing. Future work will include EPM analyses of pyrite and biotite, and LA ICP-MS analyses of pyrite. NSERC-CMIC-Footprints Exploration Project Contribution 125.

FINE FRACTION INDICATOR MINERAL SIGNATURES OF PORPHYRY, VMS AND OTHER DEPOSITS

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The use of indicator mineral methods for mineral exploration in glaciated terrain has been slowly expanding since the 1960s when they were first used for gold and diamond exploration. Today, indicator minerals are used for exploration for a broad range of commodities including diamonds, gold, PGE, and base metals. For indicator minerals to be effectively recovered from till samples, they must be sufficiently dense to allow separation and concentration from till using gravity methods. Indicator minerals are generally present in low concentrations within till (ppb levels), and therefore large samples (10-20 kg) are commonly necessary to obtain significant and useful numbers of grains in a sample. After density separation, the resulting heavy mineral concentrate (HMC) samples are sieved to a desired fraction for examination under a binocular microscope. Grain size has traditionally been a limiting factor on analysis, as material smaller than 0.250 mm is too small to manipulate accurately and increasing grain counts make thorough examination impractical. The first phase of this study has focused on the handling and effective separation of <0.250 mm HMC material into meaningful size fractions. The fine grain size makes material loss and contamination a serious concern, and thus the authors have designed proprietary, single-use sieves that can be disposed of between sample runs. This eliminates the chance of cross contamination between samples due to ineffective cleaning. Protocol for the effective handling of this fine material, focusing on minimizing loss and contamination while maintaining the efficacy of the sieving procedure, have been designed and implemented. The observed grain size distributions and material loss within the four size fractions chosen for study have given superior results than those obtained with standard stainless steel laboratory sieves. The next phase of study (currently ongoing) sees the mounting of each size fraction into epoxy ring mounts, which are subsequently quartered and reassembled into a second mount, giving a planar surface with both basal and cross sectional surfaces available for SEM analysis. This study will utilize a scanning electron microscope equipped with an energy dispersive x-ray spectrometer (EDS) and Mineral Liberation Analysis (MLA) automated quantitative mineralogy software to enable rapid quantification of the modal mineralogy and grain size/shape characteristics of <0.250 mm HMC. The resulting MLA scans will allow the construction of mineralogical databases for each sample and the characterization of each fraction of till.

CARBONATE ISOTOPES OF SHELLY FAUNA DESCRIBE LATE-PLEISTOCENE-HOLOCENE DEPOSITIONAL ENVIRONMENT IN THE HURON BASIN, ONTARIO, CANADA

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Southern Ontario has experience major hydrological and climatic changes since the retreat of the Laurentide Ice Sheet. Carbon and oxygen isotopic compositions of shells found in the preserved sediments of post-glacial lakes and rivers can give us a better understanding of environmental conditions during their formation. Shells have been analysed from nine sites ranging through three lake phases; Algonquin, Transitional, and Nipissing. These sites also represent three aquatic environments; fluvial, estuarine, and lacustrine. Gastropod shells were chosen for study because of their ubiquity over the timeline and their abundance at all sites. Three distinct clusters of data emerge that directly reflect the depositional environment of the shell. Fluvial sites have lower average $\delta^{18}O$ (−13‰) and exhibit the greatest antipathetic $\delta^{18}O$-$\delta^{13}C$ covariation, up to 10‰. This is representative of the dynamic range of water sources in fluvial systems. Lacustrine sites have higher average $\delta^{18}O$ (−6‰) and $\delta^{18}O$-$\delta^{13}C$ shows no covariation during times of open hydrology, but a distinct $\delta^{18}O$-$\delta^{13}C$ negative correlation when the water body becomes isolated. Shell isotopic compositions from estuarine environments (average $\delta^{18}O$ −10‰) lie between those of fluvial and lacustrine settings. Depositional environment played a much greater role in determining shell isotopic composition than did regional climate conditions. Care must be taken to ensure that depositional environment is well ascertained before interpreting stable isotopic data for shelly fauna common to all three settings.

REGIONAL DISTRIBUTION AND SPATIAL PATTERNS OF RECENT SHALLOW-WATER BENTHIC FORAMINIFERA FROM PUNTA CHIVATO, GULF OF CALIFORNIA, MEXICO

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Benthic foraminifera are a group of marine organisms hypersensitive to climatic fluctuations along environmental gradients, making them invaluable for understanding the parameters dictating species abundance and diversity. Environmental gradients influence species abundance and diversity, but the effect of transitional tropical to temperate environmental gradients on species assemblages has not been extensively examined. The Gulf of California, an 800-km-long narrow marginal sea, provides an ideal setting for investigating the spatial distribution and diversity of transitional recent warm-temperate to subtropical shallow-water foraminiferal assemblages along environmental gradients. The temperatures and nutrients along the western coast of the Gulf of California transition north-south from warm-temperate eutrophic to subtropical oligotrophic. Our study site on the Punta Chivato shelf, located in the central gulf region, is characterized by warm-temperate mesotrophic to eutrophic conditions throughout the year. Here, shallow water carbonate production is dominated by extensive rhodolith (free-living coralline algae) beds.

Analysis of approximately 6,000 benthic foraminifera from 20 sediment surface grab samples over a depth range of 4-53 m along the Punta Chivato shelf identified 81 species. Cluster analysis performed on species with a relative abundance higher than 1% identified four bathymetry-delimited assemblages. The assemblages are arranged in a series of concentric

circles northwest from Isla Santa Inés with assemblage IV corresponding to the innermost circle, followed by II, III and I in successively deeper waters. Assemblage distribution was further compared to previously established acoustic seafloor facies, which characterize the Punta Chivato seafloor according to substrate type. Assemblage I and III exhibit distinct species composition across marginal rhodolith-dominated to transitional bivalve-rhodolith acoustic facies. Assemblage I (12-53 m water depth) is dominated by *Quinqueloculina* (32%), *Hanzawaia nitidula* (12%), *Textularia conica* (9%), *Cibicides fletcheri* (8%), and *Poreoponides cribrorepandus* (8%). Meanwhile, Assemblage III (4-22 m water depth) is dominated by *Quinqueloculina* (46%), and *Textularia conica* (20%). Assemblage II (6-40 m water depth) is dominated by *Textularia* conica (16%), Quinqueloculina *compta* (20%), and *Elphidium crispum* (8%) across marginal rhodolith-dominated and fine-grained molluscan acoustic facies. Located northwest of Isla Santa Inés characterized by a rhodolith-dominated facies, Assemblage IV consists of *Poreoponides cribrorepandus* (40%), *Quinqueloculina compta* (27%), and *Massalina durhami* (18%). The bathymetric and spatial delimitation of each assemblage indicates the existence of distinct depth zonations, with *Quinqueloculina* dominating most assemblages. Furthermore, the presence of <20% Cibicides, >15 species of Quinqueloculina, and <5 species of large foraminifera indicate that all Punta Chivato assemblages are characteristic of warm-temperate benthic foraminiferal facies.

BENTHIC FORAMINIFERA ASSEMBLAGES FROM ISLA SAN JOSE, GULF OF CALIFORNIA, MEXICO

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Isla San Jose is an island located in the warm-temperate southwestern region of the Gulf of California, Mexico. The island is surrounded by a carbonate shelf separated from the Baja California peninsula by a narrow 450m wide channel. The shelf contains widespread rhodolith (free-living coralline algae) - dominated carbonate facies that cover an area of 18km^2 at a mean depth of 28m. Additional sediment producers on the shelf include mollusks, hermatypic coral including free-living *Fungia distorta* and abundant benthic foraminifera making this setting a transitional heterozoan to photozoan carbonate regime. Here, we investigate foraminiferal biofacies using Recent seafloor sediments collected in 2002. Results from a cluster analysis of 10 carbonate sediment samples showed two distinct foraminifera facies assemblages. Assemblage 1 was characterized by 82% of *Quinqueloculina spp*. and 18% of other foraminifera consisting of *Poroeponides cribrorepandus, Peneroplis pertusus pertusus*, and *Triloculina inflata*. Assemblage 2 consisted of 70% *Quinqueloculina spp*. and 30% of *Poroeponides cribrorepandus, Peneroplis pertusus pertusus*, and *Triloculina inflata*. In both assemblages, the most dominant species identified was *Quinqueloculina lamarkiana*. When comparing foraminiferal facies to previously established carbonate biofacies at Isla San Jose it becomes evident that samples from Assemblage 1 are located within rhodolith-dominated seafloor substrate, while Assemblage 2 samples are restricted to rhodolith-bivalve-coral biofacies and bivalve-bryozoa biofacies. Overall, both assemblages show a decrease in the abundance of the genus *Quinqueloculina* with increasing water depth. In conclusion, the foraminiferal species assemblages identified reveal characteristics of warm-temperate shallow water carbonate environments.

LAUNCHING YOUR RESEARCH: INTERNATIONAL FIELD-STUDY EXPERIENCE IN SAN SALVADOR, THE BAHAMAS

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"*Launching your Research"* (utm290) is a second-year, multidisciplinary field research course offered at the University of Toronto Mississauga (UTM) focusing on the effects of anthropogenic activities on tropical ecosystems. This course provides hands-on, research-based learning to UTM students from a broad spectrum of disciplines targeting one of the most interdisciplinary challenges facing our society: mediating the effects of global anthropogenic climate change. Exposing undergraduate students to research experiences has been demonstrated to result in drastic positive impacts in academic success, in addition to fostering lifelong learning in science, technology, engineering and mathematics (STEM), therefore resulting in a more scientifically-literate society. Launching your Research focuses on team-based research initiatives where students ultimately lead every aspect of designing and undertaking a comprehensive research program. This includes 1) designing a research project complete with a testable hypothesis, 2) identifying critical methodologies and sampling techniques that will allow the students to test their hypotheses through the use of state-of-the-art methodology and instrumentation, 3) hands-on gathering of primary, field-based data, 4) rigorous interpretation of the trends highlighted during data processing at UTM, and 5) broad dissemination of the novel results through peer-review publishing and attendance at conferences. In order to have students appreciate how scientific research is conducted and disseminated, a scaffolded approach was utilized in which the final goal of producing a peer-reviewed publication from their research work was divided into weekly tasks that highlight important skills typically only learned in graduate school. Based on student interests, and in order to transfer the necessary experiential skills to the students, a project was undertaken that would allow for an evaluation of the heavy metal accumulation in benthic formaminifera as a result of anthropogenic activities on San Salvador Island (The Bahamas). Sediments were sampled from four specific sites using a 70 cm PVC corer. The deepest 6 mL of each sample was compared to surface samples from the same core at each site. Foraminifera species were separated manually from sediment, cured with Rose Bengal dye and qualitatively scored for preservation quality. Elemental analysis was done by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP OES) to assess metal accumulation in modern foraminifera at the surface, relative to ancient foraminifera obtained from subsurface sampling.

INFLUENCE OF THE PRESENCE OF GAS PHASE ON THE ROCK DEFORMATION PROCESSES: A NUMERICAL STUDY

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It is widely known that presence of liquid in porous medium can significantly affect its mechanical properties. Pore fluids decrease the effective stress supported by the rock mineral frame. Effective stress concept is extensively used in characterization of mechanical rock behavior, and knowledge of how stress state of rock mass changes with time is essential for prediction of rock failure.

Because pore liquids in fact are multicomponent and can contain dissolved gases, various physical and chemical processes govern the interaction between different phases, increasing the likelihood for pore pressure changes. Consequently, pore content and volume, external stress and temperature are interrelated parameters. The aim of the current work is to model the pore-pressure response to changes of confining stress when dissolution or exsolution processes occur.

The current numerical study focuses on gas-liquid interaction where water is the liquid phase and carbon dioxide the gas phase. Temperature is set constant. The numerical model solves the system of differential equations describing diffusion of gas from dissolved to free state, which occurs after bubble nucleation in solution, and the resulting altered fluid-gas pressure acting on the solid boundaries. Implementation is done through iterations with changing time step. Mass-transfer happening due to gas bubbles exsolution is responsible for resulting pressure build-up (as a function of time), which is the target output calculated in the model.

Obtained results demonstrate general accordance with known experimental data, but also reveal sensitivity of output pressure curves to intensity of bubble nucleation expressed in terms of number of appearing bubbles together with their sizes. It should be noted that consideration of symmetric situation with sudden external pressure raise is possible, however, this step was not implemented in current study and is planned for realization. The shapes of pressure and concentration curves prove adequacy of the model: gas gradually exsolves from liquid until new equilibrium is reached so that eventually both pressure and concentration of dissolved gas reach plateau.

Technical Session 5: Economic Geology Sponsored by the SEG

SYNTHETIC APERTURE RADAR FOR GEOLOGICAL MAPPING SALT DIAPIRS, AXEL HEIBERG ISLAND, NU.

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Satellite remote sensing is becoming increasingly important in economic geology. Traditional geological field mapping techniques are time consuming, costly, and are frequently seasonally restricted in places like the Canadian Arctic where daylight and weather constrains fieldwork to summer months. Therefore, there is a need to improve remote mapping methods using available satellite technology. Synthetic Aperture Radar (SAR) is an underused tool in remote geological mapping. Here, we introduce SAR in combination with thermal infrared

spectroscopy as a tool for remotely mapping evaporitic anhydrite and gypsum diapirs in the Canadian Arctic prior to ground-truthing in the field.

Diapirs are economically valuable, as they commonly provide structural traps for petroleum reservoirs and lead-zinc ore deposits. This study characterizes the radar signatures of diapirs and remobilized salts on Axel Heiberg Island, Canada, which hosts the second highest concentration of diapirs in the world. Because evaporites have lower hardness and increased solubility than other sedimentary rocks, diapirs erode readily and have rough surface expressions. In contrast, remobilized salt sediments are distributed to radar-smooth slopes and river valleys. Whereas spectroscopy alone will detect both diapiric and remobilized salts, SAR is sensitive to surface roughness at the scale of its wavelength, and can be used to differentiate between smooth deposits and rough diapirs in conjunction with Landsat-8 contextual images. By combining SAR with orbital spectroscopic data, it is possible to locate salt signatures and determine if they are diapiric based on their perceived roughness.

Six fully polarimetric RADARSAT-2 C-Band (~5.5 cm) and nine PALSAR-1 L-Band (~23.6 cm) have been acquired over Axel Heiberg Island. These images have been processed and terrain corrected to produce circular polarization ratio (CPR) mosaics, which can be used to quantitatively assess surface roughness. Evaporite-rich regions are identified via spectroscopic signatures using composite imagery from ASTER Thermal Infrared (TIR) bands 10, 11, and 12. Mapped TIR signatures are imposed over CPR images contrasting CPR signatures for diapiric and deposited anhydrite exposures. Using radar two wavelengths constrains surface roughness of the salts at different scales. Salt diapirs appear moderately rough in both C and L bands. In contrast the remobilized deposits appear consistently smooth in C-Band, but some deposits appear rough in L-Band – possibly a result of grain size distribution in the river valleys.

PD DEPORTMENT IN THE NO-SEE-UM ZONE OF THE LAC DES ILES COMPLEX, ONTARIO

Wang, Yining & Mungall, James E.

As a major contribution to Pd production in Canada, the Lac des Iles Complex (LDIC) contains a “No-see-um” zone which is characterized by very low sulphur concentration (0.001251 wt%). The Lac des Iles Complex formed 2,689±1 Ma (Stone et al., 2003) and intrudes Archean tonalitic gneisses of the southern Wabigoon Subprovince (western Superior Province) (Djon & Barnes, 2012). Scanning Electron Microscope and electron microprobe groundtruthing and Pd mass balance are done on samples collected from the five rock samples from the No-see-um Zone of North Roby Zone, and one sample from the Roby Zone, to study the origins of Pd mineralization.

Rock samples used in the study represent a range of degrees of alteration, from fresh gabbronorite to altered greenschist facies. Mineral assemblage in the gabbronorite samples is characterized by plagioclase and orthopyroxene/clinopyroxene. Fresh samples see only slight overprint of chlorite, actinolite, talc, and zoisite in interstitial areas. In the more altered samples, pyroxenes are predominantly replaced by secondary minerals such as actinolite, talc, chlorite and zoisite, while plagioclase experiences a relatively less degree of replacement.

Pyrite, chalcopyrite, pentlandite and millerite are the dominant phases of sulphide found in both fresh and altered samples. In the three fresh samples (average Pd grade = 6.11 g/t)

groundtruthed using the Scanning Electron Microscope, more than 70% of Pd-bearing grains are associated with sulphides (based on 50 grains). In the more altered samples, only 6.79% of the Pd-bearing grains are associated with sulphides. This implicate some sulphide remobilization during later hydrothermal alteration events.

The major Pd phases in all the six samples include Stillwaterite (Pd8As3), Mertieite (I) ($Pd_{11}(As,Sb)_4$), Vincentite ($(Pd,Pt)_3(As,Sb,Te)$), Kotulskite (PdTe), Vysotskite (PdS) and Braggite ((Pd,Pt)S). The Pd phases show a shift from Pd/Pt sulphide phases to arsenic and tellurium enriched phases, with increasing degrees of alteration. Based on monolayer grain mounts with heavy metals seperated from rock samples, 99.13% of the total Pd mass is accounted by palladium arsenic/antimony/tellurium phases, and only 0.87% of the total Pd mass is accounted by both vysotskite and braggite in the altered samples. For fresher samples, however, up to 80% of the total Pd mass is accounted by vysotskite and braggite, and only 20% by the arsenic/antimony/tellurium bearing phases. The kotulskite grains in fresh samples also show exsolution texture from vysotskite. Mertieite (I) grains isolated from sulphide grains also show influence by late magmatic or hydrothermal fluids, which caused the replacement of S by As/Te/Sb.

Technical Session 6: Igneous and Metamorphic Geology and Geochemistry

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USE OF ANISOTROPY OR MAGNETIC SUSCEPTIBILITY (AMS) TO ANALYZE PETRO-FABRICS IN CU AND PGE BEARING GABBROIC UNITS OF THE MARATHON CU-PGE DEPOSIT, ONTARIO

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Petrofabric assessment of Cu and PGE bearing gabbroic units has been conducted on oriented drill core samples obtained from the Main Zone of the Marathon Cu-PGE deposit. Samples taken from three oriented drill cores representing mineralized and non-mineralized zones were analyzed using Anisotropy of Magnetic Susceptibility (AMS). These magmatic Cu-PGE sulphide deposits are proposed to have formed by intrusion of a crystal mush within a magma conduit setting. Magnetic anisotropy is influenced by the preferred orientation of the long axes of grains of magnetite, which is similar to the overall petrofabric of the samples defining the flow direction of the crystal-bearing magma. Susceptibility ellipsoids constructed from analysis of AMS measurements were plotted on a Flinn diagram to investigate the dominant petro fabric textures, indicating the presence of a well-defined planar fabric. Samples that gave results of the highest degree of planar fabrics were from the Two Duck Lake Gabbro

lithology; the lithological host of most of the Marathon deposit. Stereonet projection of the directional distribution of the susceptibility ellipsoid maximum and intermediate vector directions gives a well-defined planar fabric orientation of strike 177 and dip 25° to the west, in excellent agreement with proposed flow direction based on 3D modeling of footwall troughs containing the higher grade mineralization. A fabric lineation has also been detected for drill cores obtained from the Main Zone with an average trend of 295 and a plunge of 29° reflecting the likely direction of origin for the magma. Samples obtained from W-horizon area of the Marathon deposit also indicate strong planer fabric foliations. The AMS fabric orientation is a potentially useful tool to independently quantify flow structures in magmatic systems.

EXPERIMENTAL CONSTRAINTS ON CALCIUM ISOTOPIC FRACTIONATION IN CARBONATED MELTS

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Calcium is the fifth most abundant element in the Earth and as a lithophile element, does not partition into planetary cores. Thus, the Ca isotopic composition of the Earth's mantle represents the bulk Earth, making it a potentially valuable tool for studying planetary bodies and mantle evolution [1]. Currently, the $\delta^{44}Ca/^{40}Ca$ value for the upper mantle is estimated to be 1.05±0.04‰ [2]. Recent studies of Ca isotopic fractionation between co-existing clinopyroxene and orthopyroxene in mantle peridotites have measured the $\delta^{44}Ca/^{40}Ca$ to be 0.36-0.75‰ heavier in the orthopyroxene [2]. This is believed to be primarily a function of the Ca-O bond strength (ie., stronger bonds favour heavier isotopes) as well as the chemical composition (e.g. Ca/Mg) of the minerals [3]. However, the influence of temperature, pressure, minerals and their source melts, and the effect of metasomatic processes are all poorly constrained.

A series of piston cylinder and multi-anvil experiments designed to equilibrate Cpx and a carbonated silicate melt were conducted at pressures ranging from 3 to 5 GPa and temperatures from 1375 to 1450°C. Another series of piston cylinder experiments designed to equilibrate Cpx and a carbonatite melt were conducted at 3 GPa and at temperatures from 1250 to 1550°C. Additionally, one experiment was conducted at 1 GPa and 1125°C to equilibrate Cpx with a silicate melt. Ca was purified from sample matrices using ion exchange chemistry in the GEOMETRIC lab at Western. Isotopic compositions were measured by Thermo Neptune MC-ICPMS at Trent University. Initial results show significant fractionation between the carbonated silicate melt and Cpx with the $\delta^{44}Ca/^{40}Ca$ in the Cpx being 0.74-1.03‰ heavier than in the melt phase.

Mineral separates from natural mantle sourced rocks (carbonatites, kimberlites, and peridotites) were also analyzed for their Ca isotopic compositions. Our results show $\delta^{44}Ca/^{40}Ca$ values in the carbonatites and kimberlites ranging from -0.5‰ to +1.84‰ in the carbonate phases relative to the silicate phase (ie., pyroxene). Another pair of co-existing peridotite Opx and Cpx minerals were measured and the $\delta^{44}Ca/^{40}Ca$ in the Opx was 0.52‰ heavier than the

Cpx, agreeing well with the currently accepted range of variations between mantle Opx-Cpx pairs.

Fractionation factors between mantle minerals and the melts from which they are derived are important for using calcium as an effective mantle geochemical tracer. Understanding the systematics of Ca isotope fractionation in carbonatite-silicate systems will potentially allow us to use Ca isotopes as geochemical tracers of carbonatite magmatism.

[1] Kang J.-T. et al. (2016) Calcium isotopic composition of mantle xenoliths and minerals from Eastern China. *Geochim. Cosmochim. Acta* **174**, 335-344.

[2] Huang S., Farkasˇ J. and Jacobsen S. B. (2010) Calcium isotopic fractionation between clinopyroxene and orthopyroxene from mantle peridotites. *Earth Planet. Sci. Lett.* **292**, 337–344.

[3] Feng C., Qin T., Huang S., Wu Z. and Huang F. (2014) First principles investigations of equilibrium calcium isotope fractionation between clinopyroxene and Ca-doped orthopyroxene. *Geochim. Cosmochim. Acta* **143**, 132–142.

Technical Session 7 and 8: Geophysics

VIBRATION MONITORING AT A WIND TURBINE SITE IN PORT ALMA

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This study examines the vibrational effects from operating wind turbines at a site in Port Alma, Ontario. There has been a huge growth in wind turbine farms in southwestern Ontario in the last few years. Few studies have been conducted on the vibrations produced from these wind turbines. These turbines are commonly manufactured from non-Canadian companies, where studies have been conducted. However, placing a similar structured turbine from another country with different soil properties on Canadian soil may have different impacts. It was assumed that as distance increased, vibrations from the wind turbine would reduce and have less impact on the soil.

This survey was conducted over a two-day span at the Port Alma wind farm. Triaxial seismometers were setup at various distances South (up to 130-m), West (up to 275-m), and North (up to 1000-m) from the turbine and recorded the surface wave vibrations over 1-8-hour periods. Kruger Energy provided metrics associated with the turbines function (e.g., rpm) and wind direction and speed. The vertical-component recordings were filtered and converted to Fourier and power spectral density (PSD) spectra. Horizontal-to-vertical (H/V) spectral ratios and potential correlations between turbine operation and recorded vibrations were also examined.

All recorded vertical amplitudes over time were less than 0.2 mm/s, within ‘not felt’ and ‘weak’ shaking levels (Worden & Wald, 2016) and decayed up to 600-m away, but increased past this. Positive correlations between recorded amplitudes and turbine operation (wind speed and rpm) are determined. Amplitudes decreased when the turbine was turned off at distances

close to the turbine; past 850-m distance this amplitude change was not seen. From the PSD and Fourier Spectra, frequencies of 3-4, 5-8 and 24.2 Hz are the highest vertical amplitude peaks observed during the turbine's operation. As the distances increased, the higher frequencies reduced rapidly and/or the seismic background noise became more dominant at farther distances. The H/V ratios display a consistent 'double peak' 1.6 and 2.7 Hz response, observed past the 30-m radius of the turbine. Thus, it was interpreted that the 'natural' site response are these two frequencies which is observed to amplify slightly above the 'normal' background seismic noise levels by turbine generated vibrations.

These findings provide preliminary information into the unknown vibrational effects of a wind turbine on soil in southwestern Ontario. Further studies would need to be conducted to gain a better understanding of the implications at this site.

BEST STRATEGIES AND PRACTICES FOR EARTHQUAKE SITE CHARACTERIZATION AT ONTARIO BRIDGE SITES

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Sufficient knowledge about site conditions - such as the type of soil and underlying bedrock - is very important in designing structures such as buildings and bridges to withstand earthquake shaking. How a region responds to the seismic wave generated by earthquakes and its corresponding damage is largely dependent on the soil/rock types through which it propagates. The effects of site conditions on propagating seismic waves can be understood by studying the response of a soil layer overlying bedrock. This is done through the determination of the shear wave velocity of the soil layer and the impedance ratio between bedrock and the soil. Currently the seismic design of new buildings and bridges (as stated in the 2015 Canadian building and bridge codes) requires determination of the shear-wave velocity of the upper 30 metres of a given site. However, there is a concern about the effective methods amongst the wide range of geotechnical testing techniques for measuring the shear wave velocity with depth and this is where engineering seismologists have stepped in to develop best strategies/practices for determining earthquake site response.

Two methods; multichannel analysis of surface waves and passive seismic (ambient noise) method will be used to determine the time average shear wave velocity to 30m depth (Vs30) at chosen bridge sites in Ontario. The results will improve our knowledge about fast and effective seismic techniques to estimate Vs30. Where applicable, more than one technique may be appropriate to assess effects of soil velocity structure. The cheapest methods that provide the most reliable Vs30 will be tabulated for each of the chosen bridge site. This will impact how seismic site classification (Vs30) is incorporated in the sustainable design of high risk infrastructures to reduce the impact of future earthquakes and thereby provide an overall safety for commuters.

INVESTIGATION OF THE IMPACT OF PRE-EXISTING FRACTURES IN ENHANCED RESERVOIR TREATMENTS

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Hydraulic fracturing treatment methods are used to increase the permeability of hydrocarbon or geothermal reservoirs that have very low in-situ permeability. Hydraulic fracturing (HF) is performed by injecting fluids at high pressures to induce fracturing and re-fracturing of the reservoir rock, thus increasing its permeability. The pre-existing fracture networks play a crucial role in controlling the propagation of the newly induced fractures, which is of considerable interest in HF operations, as it has direct impact on cost, environment and public health. However, reservoirs that require to be hydraulically treated are typically kilometers deep, making the installation of instrumentation and prolonged monitoring of the treatment challenging. During injection, as the reservoir begins to fracture and existing fractures open/slip, strain energy is released. This energy travels as seismic waves which can be detected with highly sensitive monitoring equipment (geophones, accelerometers, etc.) and traced to their source locations. Therefore, seismic energies emitted as a result of the injection can be used as an indirect method of monitoring the treatment.

In this study, insights regarding the mechanisms of induced fracturing and seismic activity during HF treatments and the role of pre-existing fractures are investigated using the hybrid finite-discrete element method (FDEM). Numerical models are created based on a pre-fractured oil-bearing carbonate reservoir in the Upper San Andres formation. Several pre-existing fracture networks in the numerical models are generated with varying orientation, length, and fracture density to account for the uncertainty of the given fracture parameters. Through analyzing detected seismic events in the field and the numerical models, interpretation of fracture mechanisms and the role of pre-existing fractures are carried out.

FRACTURE PROPAGATION CHARACTERISTIC AND MICROMECHANICS ANALYSIS OF UNCONVENTIONAL RESERVOIR SANDSTONE USING ACIDIZING PROCESS AND INDENTATION EXPERIMENT

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This study focuses on the acidizing pretreatment and indentation tests on the unconventional (low porosity and low permeability) reservoir rock samples. In hydraulic fracturing, the fracture pressure is one of the most key parameter. The acidizing could not only influence on the fracture pressure, but also could change the indentation tests result, and then, the mineral composition, rock physics parameters, pore structure and rock strength tests results. After acidizing and indentation, a series of Scanning Electron Microscope(SEM) methods to do the rock-sample thin-section observations are compared in this research. From the SEM pictures and test results, the mechanism characteristic, the microstructure changes of

rock could be analyzed from the acid injection test. As the result, the micromechanics and fracture characteristic are changed. Especially, the fracture pressure is reducing after the acidizing. Thus, it provides a series of theoretical basis for hydraulic fracturing complex acidizing technology and improves the prediction of fracturing stimulation effect in the future.

FOLD SEGMENT LINKAGE AND UPLIFT RATES ALONG THE JANAURI AND CHANDIGARH ANTILCINES, NORTHWESTERN INDIA

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The deflection of the Sutlej and Beas rivers in NW India is evidence for fold segment linkage and growth of the Janauri and Chandigarh blind thrust anticlines since the early Quaternary. Constraining fault geometry and slip rates along the anticlines is important for assessing seismic hazards in the densely populated frontal portion of the Himalaya. A digital elevation model (DEM) is used to perform landscape analysis to constrain uplift rates and areas of segment linkage along the anticlines. Basin shape and relief, range-scale factors such as range asymmetry and mountain front sinuosity, and segmentation and steepness of river profiles are assessed. The basin dimensions, range asymmetry and normalized steepness indices of river profiles along the Janauri anticline define six sections with varying uplift rates, with the fastest uplift rate occurring at the northwest end. In contrast, the Chandigarh anticline shows a gradual increase in total uplift from northwest to southeast along its length. The hydrologic and range-scale factors associated with segment linkage and uplift variability identified in this study can be applied to other active blind thrust anticlines to constrain fault geometry, uplift rates, and seismic hazard risk.

FINITE/DISCRETE ELEMENT MODELING OF TUNNEL STABILITY IN SWELLING SHALY GROUND

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Predicting tunnel convergence has been a historically difficult phenomenon in southern Ontario mainly due to shale-dominant bedrock coupled with strongly anisotropic in-situ stress conditions. These two factors in conjunction with temporal effects have defined the majority of constitutive models describing swelling rock mass behaviour in recent decades. Simultaneously, recent advances in numerical modeling can better address geomechanical problems of large scales, with strong applicability in deep excavations to analyze complex strains in high stress scenarios.

More recently, continuous improvements in simulating time dependent swelling mechanisms in shales have been established in Finite Element Modeling (FEM) works (Kramer and Moore, 2005) (Hawlader, Lo and Moore, 2005). In these applications of various constitutive models, the limitations of addressing tunnel stability in a FEM framework become evident in addressing materials in their post-yield behaviour. The most notable of which are the locally

failed rock mass and liner material interactions, which can offer key insights on the deformation characteristics of tunnel support systems. With the capability of element dislocation and fracture, a hybrid Finite-Discrete Element Modeling (FDEM) algorithm, Y-GEO (O.K. Mahabadi, 2012), has been modified with the multi-dimensional time-stress dependent constitutive model for swelling strains established by Hawlader, Lee and Lo, 2003 on a single element basis. By altering the nodal force algorithm to incorporate an additional Cauchy tensor due to swelling strains as well as alterations to the mechanical solver of the deformation of mesh nodes, validation of single element swelling behaviour forms the basis for larger, full scale tunnels. In the Y-GEO simulation work, through the implementation of a core modulus reduction procedure for excavation, a full scale excavation modeled after the Heart Lake storm sewer is used to evaluate the accuracy of implementation.

B.C. Hawlader, K. L. (2005). Analysis of tunnels in shaly rock considering three-dimensional stress effects on swelling. Canadian Geotechnical Journal Vol. 42, 1-12.

B.C. Hawlader, Y. L. (2003). Three-dimensional stress effects on time-dependent swelling behaviour of shaly rocks. Canadian Geotechnical Journal Vol. 40, 501-511.

G.J.E. Kramer, I. M. (2005). Finite Element Modelling of Tunnels in Swelling Rock. K.Y. Lo Symposium (pp. 1-37). London, Ontario: University of Western Ontario.

O.K. Mahabadi, A. L. (2012). Y-Geo: New Combined Finite-Discrete Element Numerical Code for Geomechanical Applications. International Journal of Geomechanics, 12, 676-688.

DEEP EARTHQUAKES IN THE LAB: DETECTION OF ACOUSTIC ACTIVITY DUE TO TRANSFORMATIONAL FAULTING ASSOCIATED WITH THE OLIVINE → SPINEL TRANSFORMATION IN FAYALITE

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In subduction zones, earthquakes are thought to be associated with faulting that arises from phase transformations. In order to test the viability of this mechanism experimentally, it is necessary to make microseismic measurements while the mineral under investigation is subjected to the pressure and temperature (P,T) environment at depth. A system has been developed capable of making *in situ* acoustic emission (AE) measurements on samples under P,T conditions representative of the upper mantle and transition zone. Experiments are performed in a 3000-ton multi-anvil press using an 18/11 octahedral cell with 6 piezoelectric transducers mounted on the rear side of the anvils. AE signals are collected at a sampling rate of 40 MHz using a triggered system and a data buffer for continuous recording so full waveforms of AE events are captured. The use of multiple transducers distributed in a microseismic array allows for events to be located within the sample through automatic arrival time picking and least squares inversion techniques. The multi-anvil apparatus constitutes an inherently noisy environment both acoustically and electrically, therefore methods of noise reduction were developed and will be discussed. This technique has been used to measure acoustic signals generated from the fracturing of quartz beads during high pressure deformation and to investigate the possibility that the phase transformation from olivine to spinel, known to

occur in subduction zones, is associated with deep-focus earthquakes (300 – 690 km depth). The analog material fayalite (Fe_2SiO_4), the iron end member of olivine, has been examined. Information about its synthesis and sintering will be discussed. Results of AE experiments on samples under high pressure (P = 4-9 GPa) and high temperature (T = 773-1273 K) conditions in the spinel stability field and experiencing deviatoric stress show acoustic events that locate within the sample in multiple experiments. To my knowledge this is the first time an olivine structured silicate mineral has demonstrated acoustic activity under conditions that would normally promote plastic deformation.

Technical Session 10: Planetary

PIECES OF THE PLANET BUILDING PUZZLE: CHARACTERIZATION OF EARLY SOLAR SYSTEM MELT ENVIRONMENTS RECORDED IN THE UREILITE, LODRANITE-ACAPULCOITE AND METACHONDRITE METEORITE GROUPS

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What were the processes that formed our Solar System's rocky bodies? The answer, in part, comes from the study of meteorites. The compositions and textures of meteorites record events that took place before the Earth was fully-formed, providing a snapshot of the early Solar System. Melt processes occurring in this primitive Solar System led to the formation of planets, moons and asteroids; the result of internal heating and surface impacts. Some early formed material now exists as asteroids that grew large enough to begin melting, but did not generate enough internal heat to complete the process of differentiation; thus crystallizing the first stages of internal melting and differentiation in their rock record. These rocks are thought to be represented in meteorite collections by the primitive achondrite groups, as well as the metachondrites. Our primary objective is to describe in detail and, where possible, carry out U-Pb dating of some of the early melt processes initiating in asteroidal bodies, and represented in meteorites, to obtain a better understanding of how and for what duration terrestrial bodies experienced the growth and melting processes that ultimately led to the formation of modern day rocky bodies. In particular, this project focuses on the ureilite, lodranite-acapulcoite and metamorphosed carbonaceous chondrite meteorite groups.

Meteorites from these groups are currently being analyzed by a consortium of laboratories at Western University, the Royal Ontario Museum and the University of Portsmouth. Analyses include variable pressure scanning electron microscopy (VP-SEM) with quantitative energy dispersive spectrometry (Quant EDS), laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), Raman spectroscopy and triple oxygen isotope analyses. Early results are showing that simply grouping meteorites together from the same parent body is a difficult task, due to similarities in compositions and textures between the known groups. This

talk will discuss how these meteorites are grouped and the importance of properly assigning these groups. The evidence of melt processes captured in this unique rock set will provide needed insight into our Solar System's formation.

OPTICAL MATURITY AND ROCK ABUNDANCE: DATING THE LUNAR SURFACE WITH REMOTE SENSING METHODS

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The Moon is under constant bombardment by meteors, micrometeorites and solar wind charged particles. Micrometeorites and solar wind charged particles alter the surface of the Moon through a variety of processes collectively known as space weathering. A surface which has accumulated effects of space weathering is called "mature", and regions relatively unaffected by space weathering are termed "immature". Meteor impacts form craters that penetrate the mature upper layer of regolith, excavate and eject immature subsurface rock and regolith onto the surface. These ejecta blankets are means of determining the relative (and sometimes absolute) age of the crater. Lunar crater ages have significant implications for understanding how the lunar surface evolves over time.

A major product of space weathering is nanophase iron metal ($npFe^0$). Micrometeorites and solar wind charged particles reduce ferrous iron in the uppermost fraction of lunar soils, forming tiny globules of $npFe^0$. These globules have a strong absorption feature in the optical wavelengths, making it detectable in remote sensing optical reflectance spectra. This led to the first global lunar maturity map, the Optical Maturity (OMAT) [1]. This measure gave a well-supported relative dating method for lunar craters. A second dataset that is also used to date impact ejecta is the Diviner Rock Abundance (RA) [2]. Using lunar nighttime temperatures, Diviner is able to separate metre scale rock from regolith. RA gives the percentage of each pixel that is covered in metre-scale (or larger) boulders. Fresh crater ejecta appears bright in RA where boulders have not had time to break down or be buried by regolith. Both of these datasets give relative ages for craters, but the Rock Abundance has recently shown promise for extension to an absolute age [3].

Ongoing work seeks to provide a robust comparative analysis of the OMAT and RA datasets. Understanding the weathering rate of ejecta in these two datasets provides insights into how the lunar surface is shaped over time. Since the two datasets look at two distinct length scales, the nano-scale for OMAT and the metre-scale for RA, this work has direct applications in the study of lunar surface evolution models and studies of long-term habitability on the Moon. Early results suggest that rocks become weathered faster than the lunar soils and current work seeks to interpret and characterize this result.

[1] Paul G. Lucey, David T. Blewett, G. Jeffrey Taylor, and B. Ray Hawke. Imaging of lunar surface maturity. Journal of Geophysical Research: Planets, 105(E8):20377–20386, 2000. ISSN 2156-2202. [2] Joshua L. Bandfield, Rebecca R. Ghent, Ashwin R. Vasavada, David A. Paige, Samuel J. Lawrence, and Mark S. Robinson. Lunar surface rock

abundance and regolith fines temperatures derived from lro diviner radiometer data. Journal of Geophysical Research: Planets, 116(E12), 2011. ISSN 2156-2202. [3] Rebecca R Ghent, Paul O Hayne, Joshua L Bandfield, Bruce A Campbell, Carlton C Allen, Lynn M Carter, and David A Paige. Constraints on the recent rate of lunar ejecta breakdown and implications for crater ages. Geology, 42(12):1059–1062, 2014