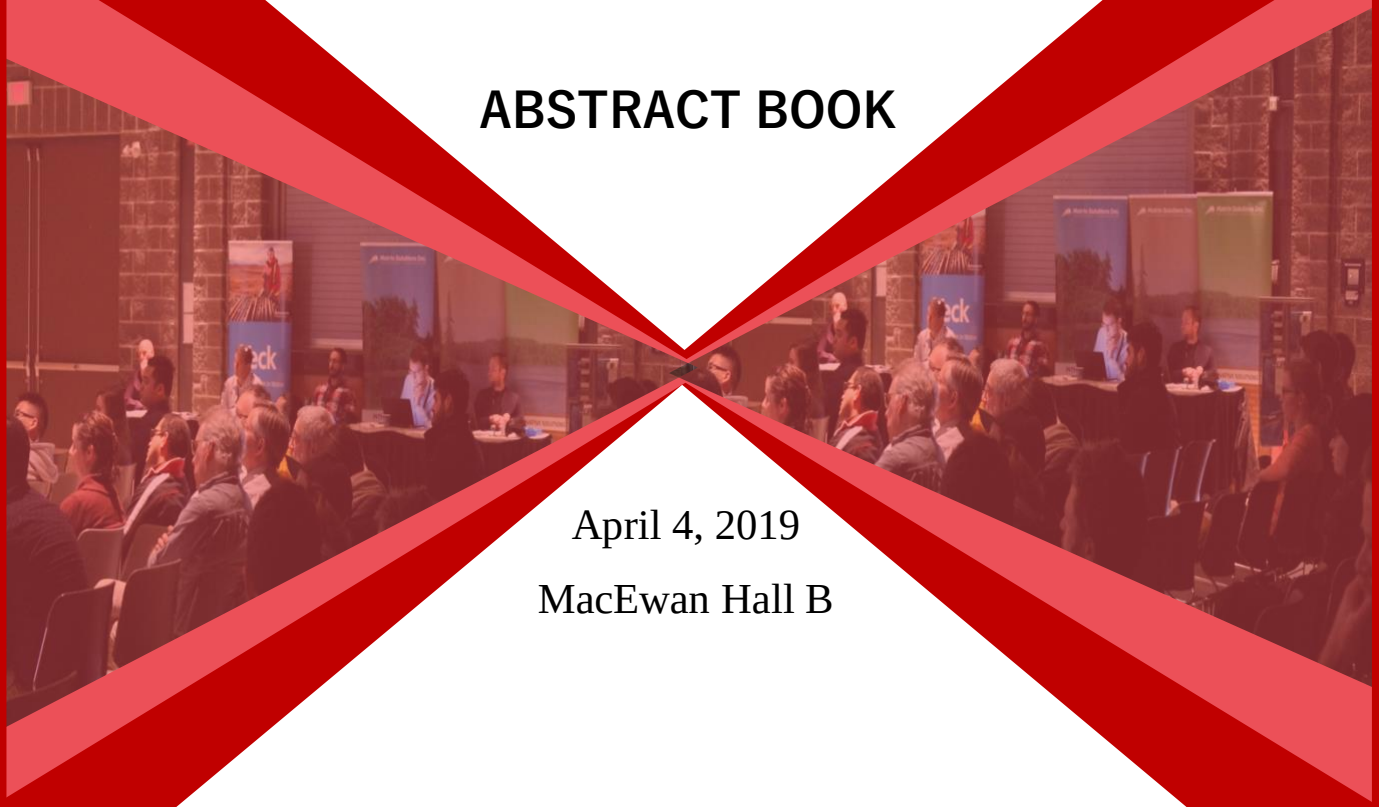
GEOREX

GEOSCIENCE RESEARCH EXCHANGE

ABSTRACT BOOK



April 4, 2019

MacEwan Hall B

Teck Imperial UNIVERSITY OF CALGARY GeoScience

PSGeoData GEOSCIENTIFIC DATA MANAGEMENT SERVICES Paramount resources Matrix Solutions Inc. ENVIRONMENT & ENGINEERING

A message from the organizers

Welcome to the eighth annual Geoscience Research Exchange (GeoREX) at the University of Calgary! We are proud to present an extensive line up of presentations and posters this year, covering a wide variety of topics in geosciences including hydrogeology, geochemistry, geophysics, petroleum geology, clastic/carbonate sedimentology, tectonics, igneous and metamorphic petrology, paleontology and palynology, and geomatics. We would also like to thank our keynote speakers Nathan Pittman and Emilia Jarochowska for sharing their latest research with us.

Over the years, GeoREX has grown into annual symposium that seeks to instill a culture of sharing and collaboration within the Department of Geoscience. Sharing our research in such a multidisciplinary environment provides us all with an opportunity to explore new ideas and seek out new collaborative efforts, all while gaining critical experience in communicating the results of our research. We hope to see GeoREX become a longstanding tradition for the students of the University of Calgary.

Finally, we would like to express our gratitude for the sponsorship from Imperial, Teck, PSGeoData Inc., Department of Geoscience, University of Calgary, Matrix Solutions Inc., and Paramount Resources Ltd. Without their support, this event would not be possible.

Welcome to GeoREX 2019, we hope you enjoy this experience!

Sincerely,

The GeoREX Committee

Dane Synnott, Wyatt Petryshen, Katie Biegel, Mastaneh Liseroudi

P.S. If you are interested in getting involved with GeoREX next year, please speak to us throughout the day or express your interest by sending an email to georex@ucalgary.ca.

PROGRAM SCHEDULE

Time	Program	Page
8:30-9:00 AM	**Doors Open, Speaker and Sponsor Setup; Hang up Posters**	
9:00-9:15 AM	**Opening Remarks by GeoREX Student Committee Members**	
	Presentation Session 1	
9:15-9:30 AM	**Stephen Schroeder, BSc** Chemical Dynamics of Saline lakes in the Cariboo Plateau, British Columbia	8
9:30-9:45 AM	**Simone Pujatti, PhD** Silica replacing pyrite and quartz sulphidisation in the TAG sulfide mound as the hallmark of the stockwork mineralization	9
9:45-10:00 AM	**Sofija Stanic, BSc** Using Silica Concentrations to Determine the Residence Times and Host Rock Contributions in the Little Elbow River	10
10:00-10:15 AM	**Sabriya Halford, BSc** The impact of the Elbow River tributaries on the mainstem river water quality based on isotopic composition and geochemistry	11
10:15-10:30 AM	**Laura Beamish, MSc** Hydrogeologic controls on groundwater discharge to fall and winter streamflow in the Canadian Rocky Mountains	12
10:30-11:00 AM	**Coffee Break and Teck Morning Poster Session**	
11:00-11:15 AM	**Benjamin Roesky, MSc** Variability in groundwater temperature discharging to a first order alpine stream as a function of flow path	13
11:15-11:30 AM	**Emad Ghaleh Noei, PhD** Trans-dimensional Gravity Inversion of Salt Structures	14
11:30-12:20 PM	**Imperial Keynote by Nathan Pittman** Improved Subsurface Characterization through Stochastic Modeling Techniques at Imperial's Kearl Mine, Alberta	5
12:20-01:10 PM	**Lunch Break/Poster Session**	
01:10-01:15 PM	**Returning Remarks by GeoREX Student Committee Members**	
	Presentation Session 2	
01:15-01:30 PM	**Haiwen Luo, BSC** High-resolution (cm-scale) characterization of the vertical heterogeneities in the Montney Formation: An Integrated Laboratory Study	15

01:30-01:45 PM	**Raza Siddiqui, MSc** High GR readings (hot-shale and hot-mud) in McMurray Formation- characterization and origin	16
1:45-02:00 PM	**Samantha Mackie, BSC** The interplay between cm- and m-scale heterogeneity of shale rocks using an outcrop case study and implications for 3-D reservoir modeling	17
2:00-02:15 PM	**Douglas Underwood, BSC** UAV's for Sedimentary Architecture: An Outcrop Study on the Blood Reserve Deltaic Sandstones, Jensen Reservoir SW, AB	18
02:15-02:30 PM	**Dominick Mallette, BSc** Comparative thermodynamic modelling of metabasites from Harpswell Neck, Southwest Maine and Whetstone Lake, East-central Ontario	19
02:30-03:10 PM	**Coffee Break and Teck Afternoon Poster Session**	
03:10-03:25 PM	**Shang Huang, PhD** Reverse Time Migration of the First-order Surface Multiple	20
03:25-03:40 PM	**Jackie Smale, MSc** Crustal and upper-mantle structure in the Canadian Cordillera from Bayesian joint inversion of receiver functions and surface-wave dispersion data	21
03:40-03:45 PM	**Introduction to the Danielle Kondla Memorial Keynote Presentation**	
03:45-04:45 PM	**Danielle Kondla Memorial Keynote by Emilia Jarochowska** Crystallographic insights into the ecology and ontogeny of conodonts	7
04:45-05:00 PM	**Prizes and Closing Statements, Take Down Posters**	
10:30-11:00 AM	**Teck Morning Poster Session**	
	***Alana Muenchrath*, BSC** Effects of land use and topography on near-surface soil properties and saturated hydraulic conductivity	22
	Tharwa Saleh, BSc Petrographic and Geochemical Evidence for Eocene Subduction-related Volcanism and Alteration near Summerland BC	23
	Sean Elliot, BSc An examination of cyclothems in the lower Strathearn Formation of Carlin Canyon, Nevada	24
	John Ferguson, BSc Investigating the biostratigraphic utility and biogeographic ranges of 'insectivorans' from the Late Uintan (Ui3) Swift Current Creek Locality (Cypress Hills Formation), Saskatchewan	25
	Emily Ellefson, MSc The Early Cretaceous in the Richardson Mountains (Northwest Territories, Canada): palynological insights on the tectono-stratigraphic architecture of the Canadian Arctic mainland	26
	Nikita Fernandes, MSc Short-Lived Return of a Calcite Sea Near the Carboniferous-Permian Boundary in Arctic Canada; Implications for a CO2 Burst in the Atmosphere	27

	Thomas Wilson, PhD Geophysical and Geochemical constraints on a regional hydrogeological model of Banff Hot Springs	28
	David Terrill, PhD Using Sr/Ca and Ba/Ca ratios to interpret trophic structure in Silurian Conodonts	29
02:30-03:10 PM	**Teck Afternoon Poster Session**	
	Qin Zhang, PhD Petrographic and numerical evaluation of the glauconite carbonation reaction as a CO2 trapping mechanism	30
	Maria Arizaleta, BSc Experimentally constraining rates of sepiolite growth at ambient conditions	31
	Shengyu Li, PhD Refining Depositional Environment Interpretation using Ichnofacies and their Potential Impact on Enhanced Reservoir Properties: a case study of Baiyinchagan Sag, Erlian Basin, China	32
	Sida Wan, BSc Recognition and Mapping of Lacustrine Deposits on Floodplains, McMurray Formation, Alberta, Canada	33
	Ryan Grieco, BSc Low-temperature thermochronology reveals exhumation pattern across the central Rocky Mountain Trench	34
	Ben Blondal, BSc Nitrate concentrations and isotope compositions in Pine Creek Wastewater effluents and ACWA streams	35
	Daniela Waldbott von Bassenheim, BSc Stratigraphy and Sedimentology of Lower Permian Carbonates, Carlin Canyon, Nevada, USA: Climatic and Tectonic Implications	36

Imperial Keynote

Improved Subsurface Characterization through Stochastic Modeling Techniques at Imperial's Kearl Mine, Alberta

Nathan R. Pittman, Adam E. Montgomery and Martin Huang
Imperial Oil Ltd.

Summary

Kearl is one of Canada's highest-quality oil sands deposits and represents the next generation of oil sands mining. Kearl has an estimated 4.6 billion barrels of recoverable bitumen resource with production levels of 220,000 bpd.

Stochastic modeling techniques have improved subsurface characterization at the Kearl oil sands mine through the integration of 3D interpretations with core data. Using depositional models, variograms, statistically controlled facies distributions and dipping model blocks the realism and predictive power of the Kearl model was improved.

Geological models used for mining applications face several unique challenges not posed in thermal or conventional reservoirs. In an environment where every block must be planned and accounted for, there is a significantly increased requirement for spatial certainty. As all material must be classified as ore or waste, the inherently different planning and handling required of these materials can lead to substantial operational cost when unplanned material classification changes occur. The impact of material misclassified as waste results in 0% recovery of those blocks and large extraction excursions are a common result of mischaracterized material processed as ore.

Commonly used deterministic modeling algorithms are simple, and while creating a representation of the subsurface at a resolution reasonable for use at larger scales, often require additional products to add realism and detail. These models are regularly accompanied by 2D interpreted cross sections to add the interpretational dipping overlay. It is common for these simplistic models to incorporate some geologic interpretation, such as facies and major surfaces, but lack the detail of dipping units.

By modeling using a combination of variograms and dip data, geologic interpretation was incorporated directly into the model. 2D seismic, dip and core data and regional sections are integrated to develop a comprehensive understanding of point bar geometries, and model layering made to honor this interpretation. Field observations, data analysis tools and depositional models inform stratigraphic geometries, which are then applied to model facies through variograms. Facies are then used to control the population of resource attributes such as bitumen saturation and fines which relate directly to ore classification and extraction performance. This approach results in a robust 3D interpretation where facies can vary in strike and dip directions in accordance with the input data and idealized depositional models. This also allows for improvements to be made to the model outside of the yearly drill program if there are changes to the understanding of the point bar system.

The use of stochastic modeling raises several challenges. The end product of statistical modeling is only one realization of a set of parameters. By populating the model using a new path or seed number, a different result can be realized. With the importance of spatial certainty in mining models, it is critical to communicate this uncertainty to end users. Similar or greater uncertainty exists between model and reality when using deterministic modeling techniques, however the single deterministic outcome provides users a false sense of certainty. It remains a challenge to quantitatively evaluate improvement to reservoir characterization as a result of new or different modeling techniques.

Applying statistically derived, dip-driven models to the Kearl oil sands mining asset allows geoscientists to incorporate interpretation directly into the model build process. It also provides a mechanism to improve subsurface characterization and add value outside of the costly pursuit of acquiring new drilling data while allowing for continuous improvement.

Danielle Kondla Memorial Keynote

Crystallographic insights into the ecology and ontogeny of conodonts

Emilia Jarochowska

GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstr. 28, 91054 Erlangen, Germany; Emilia.Jarochowska@fau.de

Conodonts were the first vertebrates to develop a biomineralized phosphatic skeleton. Their dental tools resemble teeth functionally, but their internal structure and the mechanism of growth are unique. Over nearly 300 My of their evolution, conodont feeding apparatuses achieved stupendous morphological diversity, which is hypothesized to reflect broad dietary, ecological and developmental variation. Recognizing and exploiting this ecological and histological diversity provides the possibility to explore conodonts as sensitive and highly resolved archives of environmental conditions. In order to investigate conodont adaptations expressed at the ultrastructural level, we undertook a systematic characterization of the ultrastructure of conodont dental tissues. Using electron backscatter diffraction (EBSD), X-ray diffraction, small-angle neutron scattering, and atomic force microscopy, we demonstrate that conodont biomineralized tissues have a hierarchical organization, in which mesoscopic crystals are formed by nanosized crystalline units separated with an intergranular organic sheath. This nanogranular structure is emerging as a common feature of many biominerals, associated with distinct structure-relationship properties.

Chemical Dynamics of Saline lakes in the Cariboo Plateau, British Columbia

Stephen Schroeder, Benjamin Tutolo
University of Calgary

Saline lakes and carbonate-rich headwaters represent more than 50% of inland global water by volume. In Canada, saline lakes are found in the three prairie provinces as well as inland British Columbia, and are a significant area of interest due to their unique water-chemistry evolution, as well as their potential to sequester CO_2 from the atmosphere. There are over 100 saline lakes in British Columbia with a range of chemical compositions. However, there are two dominant water types found in these saline lakes determined both by the underlying bedrock, and evaporative brine evolution. The saline lakes of British Columbia have also been found to be subject to decreased winter ice-cover due to global warming, resulting in substantial changes to their ability to uptake and potentially sequester atmospheric CO_2. Understanding the resulting changes in pH and mineral precipitation will be important to predict how the lakes' chemistry might change in the future, as well as their long-term potential to sequester atmospheric CO_2.

This project involves testing lake water samples for pH, alkalinity, and dissolved ion content, and measuring sediment samples using XRD to aid in determining lake brines sources and how the surrounding sediment and water chemistry fits into our current understanding of lake-brine evolution. The project aims to evaluate the potential of saline lakes for long-term storage of atmospheric CO_2 and provide insight on how lake chemistry might evolve in the future as winter ice-cover continues to decrease.

Silica replacing pyrite and quartz sulphidisation in the TAG sulfide mound as the hallmark of the stockwork mineralization

Simone Pujatti [1], Karin Los [2], Benjamin Tutolo [1]

[1] University of Calgary, Department of Geoscience, Calgary, Canada (pujatti.simone@ucalgary.ca)

[2] Bremen University, Department of Geociences, Bremen, Germany

The shallow subseafloor beneath hydrothermal vent fields is a dynamic biogeochemical environment with important implications for marine element cycling and the formation of sulfide ore deposits. We present detailed petrographic and geochemical analyses of core samples recovered from the Trans-Atlantic Geotraverse (TAG) hydrothermal field during ODP expedition 158. Core samples are derived from the transition between shallower pyrite-silica-anhydrite breccias and deeper pyrite-silica breccias from the TAG-1 area. In these samples, pyrite replaces microcrystalline quartz in shallow samples, whereas coarser euhedral quartz replaces pyrite in deeper sections. The recrystallization of quartz at TAG has been linked with a transition from the sulfide mound to the deeper stockwork. We provide textural evidence for coupling of the two mineral phases during recrystallization, which leads to replacement of pyrite by quartz towards the stockwork. Textural evidence of both mineral replacement reactions in the same thin section hints for spatio-temporal fluctuations of the isotherm within the mound. This can cause overprinting of the paleo-textures, or their preservation if the precipitation of anhydrite clogs the permeable pathways, leading to local isolation and thermal insulation from successive fluids characterized by different temperatures, pH, and redox state.

The evidence brought in this study for the transition between two opposite replacement styles with depth at TAG is proposed as a distinctive petrographic feature that indicates the boundary between the anhydrite zone and the stockwork. Its genetic significance aids the understanding of the mineral stratification in the active sulfide mound and in its fossil relatives found in ophiolites.

Using Silica Concentrations to Determine the Residence Times and Host Rock Contributions in the Little Elbow River

Sofija Stanic, Éowyn Campbell, Cathryn Ryan

Discharge in the Little Elbow River, Alberta, is a mixture of water from three sources; interflow, siliciclastic host rocks, and carbonate host rocks. Contributions from each source vary seasonally and during precipitation events. Delineating these dynamics is important for understanding how the river responds to melt and rain events, in turn informing our understanding of drought and floods. We collected Little Elbow water samples weekly from May to October 2018 and hourly over four storm events for 48 hour periods. Analyzing the samples for $\delta^{34}S$, H_4SiO_4, and SO_4^{2-}, we quantified source contributions using an end-member mixing model incorporating these concentrations and river discharge data. Up to 50% of river discharge came from interflow during spring melt and June precipitation events, decreasing to 40% in October baseflow. Carbonate-hosted contributions fluctuated considerably, from 27% in June to 40% in September, decreasing sharply during precipitation events and at baseflow. In contrast, siliciclastic hosted contributions were quite stable, varying only between 23-26%, increasing toward baseflow. We calculated minimum residence times in each host rock using silica concentrations. The minimum age of the carbonate-hosted river water varied considerably through the year (271-525 days), and was much older than that of the relatively stable siliciclastic-hosted water (181-225 days, older near baseflow). These findings suggest that in the Little Elbow River system, carbonate host rocks store water for longer but are more responsive to rain events compared to siliciclastic rocks which store water for shorter periods but release at a steadier rate.

The impact of the Elbow River tributaries on the mainstem river water quality based on isotopic composition and geochemistry

Sabriya Halford, Éowyn Campbell

University of Calgary, Calgary, Alberta, Canada

How much do tributaries of the Elbow River affect its discharge and chemistry? Approximately 80% of the Elbow River discharge is generated above Elbow Falls, but most human interactions with the river and its tributaries happen below the falls. The effects of these interactions on the Elbow's water quality partially depend on the tributaries' contribution to the river. We investigated tributary contributions above and below Elbow Falls by analyzing major ions, isotopic composition, and dissolved silica of monthly water samples from the tributaries and seven mainstem sites over 2016-2018. We found distinct chemistry in the tributaries compared to the Elbow River, i.e. higher H_4SiO_4 and lower SO_4^{2-} and NO_3^-. Using these concentrations, we determined that tributary waters mix primarily interflow (low silica, low sulfate) and water stored in siliciclastic rocks (high silica, low sulfate) while the Elbow also incorporates water stored in carbonate rocks (intermediate silica, high sulfate). We then assessed seasonal variations in the chemistry of the tributaries and Elbow, and determined that in high flow season (May to August) the tributaries contribute more water to the river, therefore, the Elbow River chemistry shifts closer to siliciclastic sourced waters, while in low flow season (Oct to Feb) the river appears more carbonate sourced. Accordingly, in high flow season the chemistry of the Elbow River changes notably downstream due to increased contributions from the tributaries. These findings indicate that human interactions with the tributaries have more potential to impact water quality in the Elbow River between May and September.

Hydrogeologic controls on groundwater discharge to fall and winter streamflow in the Canadian Rocky Mountains

Laura Beamish and Masaki Hayashi

University of Calgary, Calgary, Alberta, Canada

Mountain headwaters supply essential water resources to downstream communities and ecosystems. Sustainable management of these resources requires an understanding of hydrologic processes in alpine watersheds. Fall and winter streamflows in the Canadian Rockies are largely sustained by groundwater, but mountain groundwater processes are poorly understood due to the scarcity of studies in these environments. This study investigated regional variability in mountain groundwater processes using two approaches: analysis of fall and winter streamflow records from 19 watersheds in the Rockies; and hillslope aquifer modelling, to relate watershed-scale streamflow behavior to hillslope processes. In the first phase, most watersheds were observed to have a two-stage streamflow recession characterized by fast exponential decay followed by slower exponential decay. The rates of both recession segments and the timing of the transitions between the segments were determined. Results showed slower streamflow recessions were associated with younger, more porous bedrock. Rainier, lower elevation watersheds transitioned to the slow recession phase later in the fall, suggesting that the timing of the transition is climatically controlled. Records from the Bow River at Banff showed that the transition point has been shifting to earlier in the fall, potentially due to climatic change. Hillslope modelling was in progress at the time of abstract submission and aims to determine if the two-stage recessions can be explained by layering or bedrock topography in hillslope aquifers. Results from this work indicate that both geology and climate control the groundwater processes that sustain fall and winter streamflows in mountain environments.

Variability in groundwater temperature discharging to a first order alpine stream as a function of flow path

Benjamin Roesky, Masaki Hayashi
University of Calgary, Calgary, Alberta, Canada
Email: benjamin.roesky@ucalgary.ca

There is growing concern about the effects of anthropogenic climate change on stream thermal regimes especially with respect to freshwater ecosystem health. In mountain regions, reduced flows in summer months from earlier snowmelt, rising air and groundwater temperatures, and decreased shading from wildfires are all expected to contribute to stream warming. Unfortunately, there have been few field studies on groundwater contribution to streams in alpine environments making it difficult to assess how thermal regimes will be impacted in these settings. To address this need, research was conducted along a first order alpine stream in the Fortress Ski Area located in the eastern slopes of the Canadian Rockies. We found the temperature of groundwater discharging at the outlet spring to be up to 5.5°C warmer than the groundwater contribution downstream of the spring. We attribute this difference to distinct groundwater flow paths. The cold groundwater is a function of average air temperature and snowmelt. The warmer groundwater is modulated in part by an intermittent lake that contributes to discharge at the spring during the summer months. The lake warms, recharges groundwater, which then flows to the spring. Under a warming climate, a reduced snowpack would likely shorten the duration of the surface expression of the lake. This in turn would reduce the time of warm groundwater contribution to the stream, resulting in stream cooling. This illustrates the complex nature of climate change and the need to further study the effects of both intermittent and non-intermittent alpine lakes on stream thermal regimes.

Trans-dimensional Gravity Inversion of Salt Structures

Emad Ghaleh Noei[1], Jeong Woo Kim[1], Jan Dettmer[2], Michael G. Sideris[1]

[1]Department of Geomatics Engineering, University of Calgary, AB

[2]Department of Geoscience, University of Calgary, AB

This work considers the nonlinear inversion of gravity data in a Bayesian approach with a trans-dimensional self-parametrization of the subsurface that does not require regularization. Trans-dimensional parametrizations treat the number of unknown parameters as unknown, thereby applying model selection to the inverse problem which avoids regularization requirements. This parametrization describes the subsurface structure with a space partitioning of Voronoi cells. Both the number of cells and the cell coordinates are unknown parameters and estimated directly from gravity data. The density contrast is assumed to be known for the purpose of studying salt structures. The solution to the inverse problem in a Bayesian approach is considered to be given by a large ensemble of parameter sets. Here, a trans-dimensional ensemble is obtained with the reversible-jump Markov chain Monte Carlo algorithm. The ensemble provides both parameters and uncertainty estimates. We visualize the estimated subsurface structure by marginalization over the ensemble. While individual subsurface models in the ensemble include sharp boundaries, the ensemble average is smooth and objectively represents gravity data information. The inversion is applied to both simulated and measured data. Simulated data are generated for a realistic 2D diapir structure and are contaminated with Gaussian noise. The results show well-delineated structure and meaningful uncertainty estimates. Inversion of the measured data illustrates well-defined salt structure in offshore North-West Abu Dhabi with significant uncertainty estimates.

High-resolution (cm-scale) characterization of the vertical heterogeneities in the Montney Formation: An Integrated Laboratory Study

Haiwen Luo, Daniela Becerra, Amin Ghanizadeh, Christopher R. Clarkson

University of Calgary, Calgary, Alberta, Canada

Email: haiwen.luo1@ucalgary.ca

Low-permeability (tight) liquids-rich gas and oil reservoirs are currently among the most important hydrocarbon targets for the oil and gas industry in Western Canada. The current practice for exploitation tight gas reservoirs is drilling multi-fractured horizontal wells (MFHWs) along laterals. Identification of "sweet spots" using petrophysical and geomechanical evaluation methods has attracted a great focus of many research groups. These methods can be used to understand the geologic controls on reservoir quality and further provide valuable insight for optimizing hydraulic fracturing processes.

The presented work is an ongoing laboratory study, focused on identifying geochemical, petrophysical and geomechanical properties of selected cores from the Montney Formation. Six discontinuous core boxes, covering 20m-interval in the Upper Montney and 20m-interval in the Lower Montney, are analyzed in this study.

The primary objective of the current study is to characterize the vertical heterogeneities in the Montney Formation. Correlations between permeability, rock hardness, elemental and mineralogical compositions are investigated. To accomplish the goals, a suite of analyses is conducted including 1) profile (probe) permeability, 2) mechanical (rebound) hardness, 3) elemental composition (XRF), 4) XRF-based mineral composition calculation, and 5) detailed core description using gray value digitized from core images.

Based on the observations, 1) gray value correlates well with mineral composition, particularly for illite and dolomite, 2) gray value correlates well with mechanical hardness, 3) for the relatively homogenous Lower Montney, the correlation between mineral composition and permeability is stronger than the one obtained for the Upper Montney with a higher degree of lithofacies variation.

High GR readings (hot-shale and hot-mud) in McMurray Formation - characterization and origin

Raza A. Siddiqui, Milovan Fustic, Rajeev S. Nair
University of Calgary, Alberta, Canada

This study focuses on the origin and characterization of high gamma ray (GR) readings in an interval from 1AA 09-02-081-09W4 well from McMurray Formation.

A number of methods including thin section petrography, Energy Dispersive Spectroscopy (EDS), microprobe of K-feldspar, XRD, XRF and spectral gamma using scintillometer were used to investigate the interval of interest. The interval is comprised of bitumen saturated sands and intensely bioturbated mudstone. Thin section petrography shows the predominance of quartz and presence of potassium feldspar, mica, a minor amount of scattered zircon grains and traces of uranium rich monazite. Uranium recorded by EDS is likely sourced by uranium rich monazites. Small amount of kaolinite detection in XRD analyses may indirectly suggest the presence of K-feldspar and composition of K-feldspar using Wavelength Dispersive Spectroscopy (WDS) point to their plutonic origin. In contrast, embayments in numerous quartz grains suggest possible volcanic origin. Scintillometer and XRF results do not show increased uranium (U), thorium (Th) and potassium (K) in the 'hot' interval. However, XRF analyses reveal higher concentration of zirconium (more than 5 times). Zirconium spikes are consistent with results from other wells in the region. None of the commonly employed equations for calculating total gamma ray from U, Th, K were able to reconstruct the open hole logging gamma ray curve through the study interval.

Results suggest a complex provenance for these intervals. The exact source(s) of natural radioactivity remain inconclusive. Radiometric dating of observed zircons may help shed light on the age and sources of heavy minerals.

The interplay between cm- and m-scale heterogeneity of shale rocks using an outcrop case study and implications for 3-D reservoir modeling

Samantha Mackie [1], Marco Venieri [1], Scott McKean [2], Henry Galvis Portilla [1], Simon Poirier [1], Per Kent Pedersen1 [1]

[1] University of Calgary, Department of Geoscience

[2] University of Calgary, Department of Civil Engineering

In this study, we investigate the vertical and lateral heterogeneity of the Duvernay Formation, one of Western Canada's most perspective shale plays at two different scales: meter and centimeter using an outcrop-based approach. The Allstones Creek outcrop, near Cline River, Alberta (Canada), hosts one of the few Duvernay equivalent outcrops which is unique in its lateral extent, lack of weathering, and access. Hand samples and blocks were collected along three vertical stratigraphic sections that were analyzed for sedimentary facies, elemental composition, TOC, and handheld hardness. Results show compositional and mechanical coefficients of variation within a single sample can exceed 20% in relative magnitude and 70% within a single 25m vertical stratigraphic section. A direct relationship is observed between mechanical hardness and carbonate as well as silica content. As the clay content increases, hardness decreases. In addition, the lateral continuity of the outcrop offers a 2-D overview of the complex depositional architecture of the shales, providing an explanation for the geological heterogeneity of the Duvernay Formation in the subsurface. This study shows how mechanical rock properties are strongly influenced by variations in elemental composition and lithofacies within the reservoir at both meter-scale and centimeter-scale, suggesting similar reservoir heterogeneity likely occurs in the subsurface at the reservoir scale. This understanding can be applied to improve 3-D subsurface models, where upscaling often oversimplifies the reservoir and is unable to properly resolve the reservoir heterogeneity.

UAV's for Sedimentary Architecture: An Outcrop Study on the Blood Reserve Deltaic Sandstones, Jensen Reservoir SW, AB

Douglas Underwood, Per K. Pedersen

UAV technology has grown substantially over the past 10 years, creating a new way to visualize and map outcrops, while increasing efficiency and safety in the field. This study focuses on assessing the viability/accuracy of UAV geological mapping by using strictly UAV technology to re-evaluate the previously mapped Jensen Reservoir outcrops showing the Bearpaw and Blood Reserve formations. This was done by creating a high-density scan from collected UAV data, tied to survey grade RTK ground control points. Interpretations were made by mapping geologic contacts recognizable in the textured point cloud data. By using different colour manipulations of the DEM, several other geologic features are locatable in the scan and were used to assist interpretations. Then, by identifying visible sedimentary structures of the outcrop from the UAV data, rough measured lithologs were made and turned into a cross section. This combined with the integration of 3D GIS software ArcScene, lead to the creation of digital contour maps, assisting in the local 3D re-creation of the outcrop's depositional architecture.

Comparative thermodynamic modelling of metabasites from Harpswell Neck, Southwest Maine and Whetstone Lake, East-central Ontario

Dominick K. Mallette, Jacob B. Forshaw, David R. M. Pattison

Metamorphosed basaltic rocks (metabasites) are central to our understanding of metamorphism and lower-crustal processes because they are so widespread. Recently published activity-composition (a-X) relations (Green et al., 2016) have expanded our capability for predicting mineral assemblages and mineral compositions in metabasites over a wide range of pressure-temperature conditions. Recent work in high-temperature granulite-facies metabasites has indicated that whilst these models can broadly predict mineral modal percentages, they consistently display discrepancies in the composition of minerals (Forshaw et al., 2018). This study extends this investigation to lower grade amphibolite-facies rocks, providing the first quantitative comparison between natural observations and calculated phase equilibria across sequences where the conditions of metamorphism are well constrained from interbedded metapelitic rocks. Petrological modelling was applied to nine amphibolite-facies rocks from two regions representative of low-pressure Buchan-type metamorphism and medium-pressure Barrovian metamorphism, respectively: Harpswell Neck, Maine and Whetstone Lake, Ontario. The predicted phase equilibria using these latest a-X relations were compared with those using an older set of a-X relations (Holland & Powell, 1998) to assess the degree of improvement of modelling. While phase assemblages matching those observed in the samples can generally be calculated at P-T conditions that approximate those of peak metamorphism using either set of a-X relations, consistent differences were observed between the calculated and observed compositions in minerals, more significantly in the recent a-X relations for Whetstone Lake. These discrepancies question the reliability of P-T estimates made using the more recent a-X relations when conducting petrological modelling for amphibolite-facies metabasites.

Reverse Time Migration of the First-order Surface Multiple

Shang Huang, Daniel Trad

University of Calgary

Email: shang.huang1@ucalgary.ca

In seismic exploration, compared with the primary wave, surface-related multiple reflections are traditionally regarded as noise and need to be removed by the considerable effort. However, surface-related multiples can provide additional information for the complicated subsurface structure, because sometimes multiple can detect the rugose reflectors and the bottom of the salt body whereas the primary cannot. In addition, in the marine data, the amplitude of surface multiple is strong and can become a great target. Furthermore, multiples have relatively small reflection angles that can improve image resolution.

The goal of this study is to generate a subsurface image with higher resolution and illumination which can be used for a more accurate geological interpretation. Migration is a process re-locating the seismic events in the correct space or time location. Conventional migration often yields insufficient imaging information and resolution which makes the wrong interpretation. To enhance the resolution and suppress the crosstalk or artifact, reverse time migration is used in this project to image free-surface multiples. The primaries separated from the record traces are used as the virtual sources at the hydrophones, and the first-order surface-related multiples are the observed data. This method is not a replacement for other migration methods using primary reflections, but a helpful complement to improve the image quality.

Crustal and upper-mantle structure in the Canadian Cordillera from Bayesian joint inversion of receiver functions and surface-wave dispersion data

Jacquelyn Smale, Jan Dettmer, Hersh Gilbert

University of Calgary

Previous work suggests shallow crustal layers and significant structure beneath the Moho in the northern Canadian Cordillera. Such complexities make inverting for structure without making significant model-parametrization assumptions challenging. We use Bayesian model selection to receiver function (RF) and surface-wave dispersion joint inversion to choose the parametrization for crust and upper mantle objectively. Observed data are considered for station Whitehorse with 30 years of recordings and include ~7000 events between 30-90 degrees distance and magnitudes of 5.5-7.5. To reduce the influence of anisotropy and dipping layers, which cannot be addressed by this algorithm, we restrict the data between 200-270^{o} back-azimuth and 0.04-0.06 s/km slowness. RFs are calculated via water-level frequency deconvolution and dispersion curves are from the GDM52 repository. Inversion is applied with a trans-dimensional parametrization and hierarchical treatment of data errors to objectively select a parametrization by treating the discretization by layers as unknown. Discontinuities and gradient changes of shear-wave velocity with depth are inferred. The hierarchical noise treatment includes scaling parameters for full covariance matrices estimated from observed seismic noise. The inversion is applied to simulated and observed data. We invert simulated data representative of cordilleran lithosphere to examine how well gradients are resolved in the presence of complex layering. These simulations indicate that gradients and complex layering can be resolved for noise levels representative of observed data. Results from observed data suggest complex layering in the shallow crust, a Moho depth of ~35-km, and high-velocity structures in the upper mantle.

Effects of land use and topography on near-surface soil properties and saturated hydraulic conductivity

Alana Muenchrath, Edwin Cey

University of Calgary, AB

Agricultural land use practices can cause drastic and long lasting effects on near-surface soils. Physical soil properties govern hydraulic processes including water infiltration, which can have major implications for soil quality, plant productivity and hydrologic function. The main goal of this study was to compare near-surface saturated hydraulic conductivity (K_s) of a cropland and grassland field, located 80km NE of Calgary, AB. To evaluate soil property influences on K_s, soil characteristics were compared between land use practice and topographic upland and depression positions in each field. K_s rates were estimated using 30cm diameter single-ring infiltrometers. Soil ring samples were taken within each infiltrometer at depths of 0-5cm, 8-13cm and 15-20cm, and analyzed for bulk density (ρ_b), soil organic matter (SOM), grain size, and macropore density (MPD). Results revealed K_s did not significantly differ between the cropland upland, grassland upland or grassland depression, however, the cropland depression had a significantly lower K_s. Soil texture was found to be the most influential soil property on K_s, specifically, greater clay content resulting in decreased K_s rates. Macropore density also had significant effects, with greater MPD resulting in increased K_s. Land use comparison revealed lower MPD in the cropland than grassland, while SOM and ρ_b were not significantly different. The cropland showed evidence of erosional processes, and the grassland showed a difference in SOM and MPD with topographic position. Results of this study indicate that erosion in croplands may result in decreased infiltration rates in depressions, which may have negative implications for soil quality, crop yield and potential groundwater recharge.

Petrographic and Geochemical Evidence for Eocene Subduction-related Volcanism and Alteration near Summerland BC

Tharwa Saleh, Mohamed Farhat, Steve Grasby, Jennifer Cuthbertson

The Challis-Kamloops volcanic belt extends from Washington USA to Northern British Colombia, and is thought to have formed in the early Eocene through vigorous, widespread and short-lived volcanism. The types of rocks, as well as their hydrothermal alteration features, provide a window into the processes that created and modified these samples. In 1990, the Geological Survey of Canada sponsored the collection of 59 boxes of drill core with the British Colombia Ministry of Energy, Mines and Petroleum Resources from depths of 542m to 956m in Summerland in the interior of British Colombia. From the core, 114 samples have been taken to perform X-ray fluorescence whole rock chemical analyses as well as inductively coupled plasma mass spectrometry to detect trace elements. In addition to the geochemical samples, 113 thin sections have been cut from the core in intervals of approximately 10 feet.

Exploratory in nature, the purpose of this project is to describe the mineralogy and texture of volcanic rocks sampled by drill core in the Summerland area, classify and name the rocks, and use their major and trace element abundances to investigate the tectonic regime in this region of the Canadian Cordillera in the early Eocene. Further analyses of alteration products will allow for insight into the hydrothermal regime that acted upon the rocks post-deposition. In addition, this study will consider the possibility that the Marron formation, which encompasses the majority of the Summerland basin, may have the potential to host an ore body. Preliminary results show that lavas are mainly porphyritic with clinopyroxene and plagioclase phenocrysts set in a fine-grained, altered groundmass. Intervals of pyroclastic material with a fragmental texture are also present. Geochemical results indicate a calc-alkaline magma affinity, suggesting arc or back arc volcanism with a possibility of slab window modification. Study of the alteration minerals within the volcanic rocks suggests a low grade, prehnite-pumpellyite metamorphic overprint. Further studies will apply tighter constraints on the formation of volcanic rock of the Intermontane belt of the Canadian Cordillera and their subsequent alteration processes that have created the deposits we see today.

An examination of cyclothems in the lower Strathearn Formation of Carlin Canyon, Nevada

Sean Elliot, University of Calgary

During the late Paleozoic, continental USA was located in an equatorial setting as part of the Gondwana supercontinent. The Late Paleozoic Ice Age saw prominent glaciation across Gondwana from the mid-Carboniferous to the Middle Permian (Fielding et al, 2008). Global climate change in the late Paleozoic led to waxing and waning of Gondwana's glaciers causing fluctuations in eustatic sea level. Milankovitch cycles predict that climate fluctuations should occur every 100,000 and 404,000 years due to eccentricity in earth's orbit around the sun. Changes in eustatic sea level are preserved as cyclic deposits known as cyclothems, which are prominent throughout the Upper Pennsylvanian lower Strathearn Formation of Carlin Canyon, Nevada. A microfacies analysis of the lower Strathearn Formation was carried out, yielding ten distinct microfacies primarily belonging to photozoan assemblages with rare heterozoan assemblages scattered throughout the formation. A depositional model was created based on the depositional environments interpreted for each microfacies. The scale and frequency of transgressive events were analyzed based on the depositional model and duration of deposition. Applying temporal data from Dehari (2016) revealed that large-scale transgressions occurred with a frequency indicating ~400,000 year cycles, while smaller transgressions occurred with a frequency indicating ~100,000 year cycles. The cyclothems identified within the lower Strathearn display climate fluctuations corresponding to long and short orbital eccentricity as predicted by Milankovitch cycles.

References

Dehari, E., 2016. Upper Pennsylvanian-Lower Permian Carbonate Sedimentology and Conodont Biostratigraphy of the Strathearn and Buckskin Mountain Formations, Carlin Canyon, Nevada. Unpublished MSc thesis, 218 p.

Fielding, C.R., Frank, T.D., Birgenheier, L.P., Rygel, M.C., Jones, A.T., Roberts, J., 2008. Stratigraphic imprint of the Late Paleozoic Ice Age in eastern Australia: a record of alternating glacial and nonglacial climate regime. Journal of the Geological Society v. 165, p. 129-140.

Investigating the biostratigraphic utility and biogeographic ranges of 'insectivorans' from the Late Uintan (Ui3) Swift Current Creek Locality (Cypress Hills Formation), Saskatchewan

John Ferguson

Department of Geoscience, University of Calgary

The Late Uintan (Ui3; 42.8 – 41.4 Ma) Swift Current Creek (SCC) mammalian fossil assemblage from the Cypress Hills Formation, south-western Saskatchewan, is composed of 1372 specimens representing 59 genera. This fauna is particularly important as it is the northernmost mid-latitude terrestrial mammal assemblage from an interval of gradual cooling after peak warmth of the Early Eocene Climatic Optimum. The age of the SCC fauna has been primarily determined using biostratigraphic assessment of its rodent taxa in comparison with lower latitude localities. High levels of endemism within SCC rodents means the resulting age estimate is not particularly robust. 'Insectivorans' have historically been disregarded for biostratigraphy due to being a 'waste-basket' taxon with contentious phylogeny. However, 'insectivoran' fossils are abundant within the SCC fauna, comprising 12% of specimens found in this study. This study seeks to use SCC 'insectivorans' to further constrain the biostratigraphic age of the SCC fauna.

Mammal teeth were sorted from loose sediment under a dissecting microscope and assigned taxonomic categories using dental characteristics. Genus and species level classifications were compared to published temporal and geographic occurrences. Nine 'insectivoran' species were identified but only *Centetodon aztecus* appears to be biostratigraphically informative, as it correlates to known Ui3 localities. Taxa such as soricids are temporally long-lived, negating their biostratigraphic utility, while others like *Thylacaelurus campester* are endemic to SCC. High rates of SCC endemism compared to lower latitude localities may be related to the organisms' small size and geographic barriers formed by the Cordillera, although climatic influences cannot be discounted.

The Early Cretaceous in the Richardson Mountains (Northwest Territories, Canada): palynological insights on the tectono-stratigraphic architecture of the Canadian Arctic mainland

Emily Ellefson[1,2], Manuel Bringué[2], Jennifer Galloway[2,3], Steve Hubbard[1] and Thomas Hadlari[2]

[1]Univeristy of Calgary, Calgary, Alberta, Canada

[2]Geological Survey of Canada, Alberta, Canada

[3]Aarhus Institute of Advanced Studies, Aarhus University, Aarhus, Denmark

The Sverdrup Basin is a sedimentary basin underlying the Canadian Arctic Archipelago; it currently provides the primary reference framework for the tectono-stratigraphic architecture of the Canadian Arctic. It contains a nearly continuous record of the Mesozoic rifting events that led to the formation of the Arctic Ocean and associated underlying Amerasia Basin including a widespread sub-Hauterivian (breakup) unconformity. The Richardson Mountains, located in northwestern Canada, also contain a nearly continuous sedimentary record of Mesozoic events and are ideally positioned to investigate links between the tectono-stratigraphic evolution of the Sverdrup Basin and adjacent landmasses. Within the Richardson Mountains is a middle-upper Hauterivian unconformity, developed during a period of rifting and occurring erosionally at the base of the Mount Goodenough Formation. However, the precise age of the Mount Goodenough Formation, the unconformity, and its relation to polar tectonics remains uncertain.

The main aim of this project is to temporally correlate the intra-Mount Goodenough Formation Hauterivian-aged unconformity in the Richardson Mountains region with the sub-Hauterivian breakup unconformity in the Sverdrup Basin, to provide new insight into (1) the tectono-stratigraphic linkages with circum-Arctic areas and (2) the development of polar terrestrial ecosystems during a warm interval in Earth's history, both of which are important for resource assessment in the region. This will be accomplished using quantitative palynology (the analysis of organic-walled microfossils including pollen, spores and algal cysts) to statistically correlate pollen and spore assemblages from the Richardson Mountains to those published from the Sverdrup Basin to test time equivalence and reconstruct paleoenvironmental conditions.

Short-Lived Return of a Calcite Sea Near the Carboniferous-Permian Boundary in Arctic Canada; Implications for a CO2 Burst in the Atmosphere

Nikita Fernandes, Dr. Benoit Beauchamp

The Late Paleozoic transition from a calcite sea to aragonite sea extended well into the Early Pennsylvanian when calcitic algae and radial ooids remained the dominant carbonate constituents. This calcitic assemblage was global in nature as observed on both sides of Pangea. By the mid-Moscovian, aragonitic algae and tangential ooids started appearing in large numbers and flourished for the remainder of the Pennsylvanian and well into the Early Permian, indicating a complete shift to an aragonite sea. During this time however, a short-lived return to a calcite sea near the C-P boundary is recorded in shelf carbonates of the Sverdrup Basin, Arctic Canada. For a span of ~1 Ma, calcitic flora identical in composition to the Early Pennsylvanian flora reappeared in uppermost Gzhelian strata suggesting the return of conditions favorable to the precipitation and preservation of calcitic biota, while placing stress on aragonitic-secreting organisms. These observations are explained by the rapid shoaling of the aragonite saturation horizon and lysocline from a relatively deep position to a considerably shallower position near or above fair weather wave base. The return of a calcite sea in the latest Carboniferous may be driven by a burst of CO_2 in the atmosphere, which would pull the aragonite saturation horizon into shallower waters of the Sverdrup Basin. Considering that Mg/Ca ratios are unlikely to fluctuate much over short geological time, a burst of CO_2 in the atmosphere, and therefore in the ocean provides the simplest explanation for the return of a calcite sea near the C-P boundary.

Geophysical and Geochemical constraints on a regional hydrogeological model of Banff Hot Springs

Tom Wilson, Rachel Lauer, Masaki Hayashi
University of Calgary

In the Banff area, located within the Front Ranges of the Canadian Rockies, nine thermal springs occur in a linear trend along the Sulphur Mountain Thrust (SMT) fault. Previous investigations show that spring flow is driven by precipitation infiltrating the flanks of neighbouring mountains on either side of the SMT. Water entering the system permeates down through a unit of carbonate rock to a maximum depth of 3.2 km, where it intercepts the SMT and is quickly returned to the surface via the high permeability fault zone, emerging as hot spring water. In recent years the highest elevation springs have experienced late winter flow stoppages threatening the habitat of the endangered snail, *Physella johnsoni*, and causing operational interruption to a swimming pool which is fed by the Upper Hot spring. To understand the ecological threat and limit flow disruption to the pool, short- and long-term forecasts of spring discharge are required. We use geophysical and geochemical investigations to provide spatial and temporal constrains for regional scale three dimensional hydrological models of the hot spring system, which will be used to evaluate future spring discharge behaviour. Preliminary results from geophysical investigations show the springs are restricted to the lower elevation boundary of the 100 m wide SMT fault block, which is interpreted as a low resistivity zone (10 – 100's Ωm) associated with water bearing fractured rock. The fault zone strikes NNW-SSE and dips 80 degrees to the west, which is in agreement with structural geological maps of the area.

Using Sr/Ca and Ba/Ca ratios to interpret trophic structure in Silurian Conodonts

David Terrill (University of Calgary)
Emilia Jarochowska (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Conodonts are small marine vertebrates known primarily from tooth-like elements from the Cambrian to the end of the Triassic. Often found in carbonate rocks and shales, conodonts are frequently used for biostratigraphic analysis due to their abundance, rapid evolution, and diversity of morphology. Despite being studied for well over a century, little is known about the ecology of conodonts, including what they may have fed upon. This is further complicated by the common occurrence of multiple conodont taxa within the same samples. These taxa often have radically different morphologies, suggesting differing sources of nutrition between them.

One potential tool to resolve this question is the use of Sr/Ca and Ba/Ca ratios preserved in the apatite of the conodont elements. These ratios have been used as a proxy for trophic level in modern environments, as lower Sr/Ca and Ba/Ca values are produced at higher trophic levels. Here we have analyzed these elemental ratios in a number of conodont taxa from time equivalent strata in the Silurian Gotland succession in Sweden. Results suggest that some trophic signals are preserved, however this may be complicated by other environmental factors such as changes in salinity.

Petrographic and numerical evaluation of the glauconite carbonation reaction as a CO2 trapping mechanism

Qin Zhang, Benjamin Tutolo

Department of Geoscience, University of Calgary

Glauconite is an authigenic, iron-rich clay mineral that is abundant in greensands formations worldwide. Evidence from these formations suggests that glauconite is commonly diagenetically converted to FeCO3 minerals. Harnessing this natural process may provide an effective mechanism for permanent storage of anthropogenic CO2. To evaluate the potential of the glauconite carbonation reaction as a trapping mechanism for anthropogenic CO2, we performed a detailed evaluation of the mechanisms through which FeCO3 naturally replaces glauconite during diagenesis of glauconitic sandstones from the Lower Cretaceous Upper Mannville Group in western Alberta. In our examined samples, strong evidence of siderite replacement and displacement of glauconite, as well as accessory diagenetic minerals, such as kaolinite and ankerite, were identified. The majority of glauconite grains show dissolution textures, such as leached layers, and carbonation features, such as rim-encroaching siderite crystals, which together indicate that reservoir conditions were thermodynamically favorable for glauconite carbonation during burial diagenesis. Calculations based on tabulated mineral volume data suggest that the conversion of glauconite to Fe-Mg carbonates, kaolinite, and quartz generates significant porosity, which, in turn, suggests that glauconite carbonation can proceed to completion provided that geochemical conditions remain favorable for reaction. Nonetheless, abundant reductants must also be present in reservoir fluids to convert the oxidized Fe in glauconite to its reduced form in FeCO3. We conclude by performing thermodynamic calculations using recently derived thermodynamic data for glauconite to delineate the redox, pH, pCO2, and temperature conditions under which glauconite carbonation should proceed to completion.

Experimentally constraining rates of sepiolite growth at ambient conditions

Maria L. Arizaleta, Benjamin M. Tutolo, Michael Nightingale.

University of Calgary

The magnesium silicate mineral sepiolite is an important component of sediments deposited in a variety of environments worldwide, including alkaline lakes, oil and natural gas reservoirs, and diatomaceous marine sediments. Because of its widespread occurrence, it is important to understand its growth behaviour to allow for better quantitative geochemical models of these environments. Nonetheless, although some estimates of solubility and growth rates for amorphous Mg-silicates at ambient temperatures have recently been published, the growth rate of sepiolite as a function of important parameters such as pH, Mg, and Si concentrations remains almost entirely unconstrained. Thus, the purpose of this study is to experimentally constrain the kinetics of sepiolite growth at conditions applicable to the environments where it grows in nature. To accomplish this, we have performed a series of sepiolite-seeded batch and flow-through growth experiments at room temperature with varying pH and concentrations of Mg and SiO_2(aq). Growth rates of sepiolite were measured by monitoring the rate of depletion of Mg and Si from the solution during interaction with the sepiolite seed. Typical rates measured are on the order of 10^{-10} mol/m^2/s, with rate increasing with increasing pH and Mg and Si concentrations. This rate is in agreement with values obtained from one of few other studies conducted which aimed to study reaction pathways and growth rates of sepiolite, Brady (1992). Knowledge gained from this study will be used to develop geochemical models of sepiolite formation, which, in turn, will be used to interpret the evolution of modern sepiolite-forming systems as well as the paleoenvironments of sepiolite-bearing sediments.

Refining Depositional Environment Interpretation using Ichnofacies and their Potential Impact on Enhanced Reservoir Properties: a case study of Baiyinchagan Sag, Erlian Basin, China

Shengyu Li [a,b],, Milovan Fustic [b], Jingchun Tian[a], Dongdong Yang[c]*

[a] State Key Laboratory of Oil-Gas Reservoirs Geology and Exploitation, Chengdu University of Technology, China. shengyu.li@ucalgary.ca

[b] Department of Geoscience, University of Calgary, 2500 University Drive, NW, Calgary, Alberta, T2N 1N4, Canada.

[c] Exploration and Development Scientific Research Institute, Sinopec Zhongyuan Oilfield Company, China.

Baiyinchagan Sag in Erlian Basin of China is a continental faulted lacustrine basin, which experienced complex evolution during the Cretaceous. Ichnofacies proved important for refining depositional environment interpretation and reservoir characterization. Thorough observation and examination of cores were coupled with petrographic studies and porosity and permeability measurements. *Skolithos, Planolites, Scoyenia*and *Chondrites* were found in the sandstone and mudstone stratum. According to the ecological habits, they were divided into *Domichnia, Fodichnia, Pascichnia*. Relationship between lithology and trace fossils allows for classifying them into three distinct types: i) the assemblages characteristics for trace fossils developed in thick bedded sandstone. A typical example was *Skolihos* developed in gray sandstone (Well Da10, 915.00m), with bioturbation index (BI) between 1 and 3, indicating the sedimentary environment of relatively strong energy and frequent sedimentary rate variations like the high energy zone along the lakeside or the delta underwater distributary channel; ii) the assemblages characteristics for trace fossils developed near boundary between sandstone and mudstone. For example, *Pasichnia* developed in the interbedded gray mudstone and gray sandstone (Well Weng2, 1652.00m), with BI between 2 and 4, suggesting the turbidity sedimentary environment; iii) the assemblages characteristics for trace fossils developed in thick bedded mudstone. These include *Planolites, Scoyenia and Chondrites* which were relatively widely distributed in the grey mudstone, with BI between 0 and 1, indicating relatively stable energy and quiet sedimentary environment like shallow lake or delta front. Observations and physical property measurements suggested that the sediments with trace fossils might have better reservoir properties.

Recognition and Mapping of Lacustrine Deposits on Floodplains, McMurray Formation, Alberta, Canada

Sida Wan, Milovan Fustic

Recent tectono-stratigraphic reconstruction of the Athabasca Oil Sands Deposits in Northeastern Alberta (Canada) suggests the presence of extensive lacustrine deposits (Barton 2017). Stratigraphically, these deposits belong to the Lower Member of the Lower Cretaceous McMurray Formation. The formation of lacustrine deposited is attributed to increased accommodation space formed by the dissolution of underlying Devonian age Prarie Evaporites (Barton 2017). While the interpretation is supported by stratigraphic relationship and geometry of mapped mudstone dominated units, the study is not supported by detail core descriptions and documentation of diagnostic lacustrine sedimentary features as well as criteria for distinguishing lacustrine from syndepositional floodplain deposits. The role of rising sea level is also not considered.

In this study we: i) Describe sedimentary and biogenic structures in mud dominated interval in lower parts of cores from Section 4 in Township 95 and Range 11 W4M; ii) Correlate core data with unpublished field notes from a nearby outcrop (Gauging Station); iii) Interpret depositional processes including potential evidence of seasonality and sea level rise; iv) Following systematic core to log correlation create a set of regional cross-sections (in GeoScout) to illustrate architecture and stratigraphic relationship with underlying and the overlying sand-dominated units; v) Discuss implications of findings for subsurface interpretation and petroleum reservoir developments (i.e. implications to reservoir connectivity) as well as nearby mining operations (i.e. using lacustrine deposits as natural pavement surfaces).

References:

Barton, M. D., I. Porter, C. O'Byrne, and R. Mahood. "Impact of the Prairie Evaporite Dissolution Collapse on McMurray Stratigraphy and Depositional Patterns, Shell Albian Sands Lease 13, Northeast Alberta." Bulletin of Canadian Petroleum Geology65.1 (2017): 175-99. Web.

Low-temperature thermochronology reveals exhumation pattern across the central Rocky Mountain Trench

Ryan Grieco, Eva Enkelmann, Will Matthews
University of Calgary, Calgary, Alberta, Canada
Email: ryan.grieco@ucalgary.ca, eva.enkelmann@ucalgary.ca

The Rocky Mountain Trench (RMT) is a fault system that extends north from the Northwestern USA, along the western edge of the Canadian Rocky Mountains, and into Alaska. The RMT transitions from normal faulting in the south to dextral strike-slip motion farther north. The transition in faulting is thought to occur near Valemount in BC, however, the fault kinematic in this central transition area is uncertain. This study aims to identify fault kinematics in this central area of the RMT. Understanding the kinematics of deformation will contribute to the investigation of the tectonic history of the southern Canadian Cordillera.

We identify fault kinematics by quantifying the exhumation history of rock exposed on both sides of the RMT. Exhumation is inferred from apatite U-Th/He thermochronology data. Thermochronology measures the time since a sample cooled below the closure temperature, which is for apatite U-Th/He between 50□C and 70□C. As the rocks are brought to surface by exhumation, they cool through this closure temperature window. Measurement of the age of cooling on each side of the RMT therefore identifies any relative exhumation difference across the RMT. The relative relationship of exhumation ages reveals the sense fault motion. Exhumation along a 135 km section of the RMT is analyzed to identify changes in deformation history along strike. Our samples stretch from 50 km south of Valemount up north to McBride BC. Exhumation rates are also derived from age-elevation profiles that were collected on both sides of the RMT. We report 22 new apatite U Th/He ages that have been used for thermal history modelling, which together reveal Late Cretaceous to Pliocene cooling. The ages from this study will be integrated with higher temperature thermochronological dating techniques to further analyze the development of the RMT.

Nitrate concentrations and isotope compositions in Pine Creek Wastewater effluents and ACWA streams

Bentley Blondal, Veronique Fau and Bernhard Mayer

Applied Geochemistry Group, Department of Geoscience, University of Calgary, Alberta, Canada

Stable isotope techniques are an excellent tool to identify the sources and the fate of nutrients in watersheds, provided that the isotopic compositions of nutrient end-members are well characterized and isotopically distinct. The objective of this ongoing study is to characterize the temporal variability of the isotopic compositions of nitrate in waste water effluents and to assess how this isotopic composition changes along the experimental streams in the Advancing Canadian Wastewater Assets (ACWA) facility located at the Pine Creek wastewater treatment plant (WWTP) in Calgary (Alberta, Canada). Five samples were collected weekly along 3 different effluent streams at downstream distances of approximately every 20 meters. One stream contained Bow River water only, whereas the other two streams contained either post UV or ozonated effluent (3%) mixed with Bow River water. Samples were analyzed for chemical compositions and the isotopic composition of nitrate. Nitrate concentrations in the post UV effluent stream are ~1 mg L^{-1} higher than the nitrate concentrations in the stream with Bow River water over the same downstream distance. The average $\delta^{15}N_{NO3}$ values in both effluent streams are approximately 9.0 ‰, whereas $\delta^{15}N_{NO3}$ of Bow River water was +8.1 ‰, due to effluent from the Bonnybrook WWTP. There was little change in the $\delta^{15}N$ values of nitrate with downstream distance in any of three streams. These results suggest that effluents from Pine Creek and Bonnybrook WWTPs are difficult to distinguished based on their $\delta^{15}N_{NO3}$ values, but both these effluents are isotopically distinct from riverine nitrate upstream of Calgary.

Stratigraphy and Sedimentology of Lower Permian Carbonates, Carlin Canyon, Nevada, USA: Climatic and Tectonic Implications

Daniela Waldbott von Bassenheim
Benoit Beauchamp
Charles Henderson

Sedimentological and stratigraphic analysis was performed on the Lower Permian carbonate-dominated Upper Strathearn formation (USF) and Buckskin Mountain formation (BMF) of NE Nevada (Basin and Range Province). These units recorded marine deposition in the active Antler foreland basin. Two sections totalling 475.5 m were measured; 106 lithological and 8 conodont samples were collected. Conodont biostratigraphy indicates these rocks range from Asselian to Early Artinskian in age based on species such as *Sweetognathus expansus, Streptognathodus constrictus, Streptognathodus fusus* and *Mesogondolella laevigata*. Microfacies analysis revealed a variety of fabrics and fossils that were grouped into ten microfacies. Each microfacies was interpreted in terms of bathymetry, energy, circulation and temperature, representing deposition on a westerly-deepening carbonate ramp. Cyclicity in the distribution of microfacies in the USF is interpreted as reflecting eustatic fluctuations in response to the waxing and waning of Gondwana glaciations at the tail end of the Late Paleozoic Ice Age (LPIA) during the Asselian. In contrast, the Sakmarian to Artinskian BMF lacks evidence of cyclicity, which reflects termination of the LPIA and possibly contemporaneous closure of the Uralian seaway. The mostly shallow water succession described in this study correlates well with previously-published deeper water sections to the west. Whereas the USF is of equal thickness throughout the Carlin Canyon area, the BMF appears to be thick to the west, thins dramatically in the central area, and thickens again to the east, suggesting the area was under the throes of differential subsidence reflecting ongoing Antler tectonism.

NOTES