Booklet of Abstracts

Graduate student poster presentation-2023

Department of Earth and Environmental Sciences

The event will take place:
Friday September 29
2 – 5pm
Atrium of the Steele Ocean Sciences Building

We invite all undergraduate students to join the event and enjoy free food and drinks

Presentation schedule:

Lauren MacLellan

Vertical Muon Paleotopometry

Lauren MacLellan, John Gosse

The flux of cosmic ray-produced muons is monitored worldwide by particle physics labs, including Canada's 2 km deep SNOLAB. The penetrative muons interact with atoms in minerals to produce rare nuclides (e.g., 10Be and 26Al). The recent advances in accelerator mass spectrometry, sample preparation, and muon flux measurements enable the measurement of muogenic nuclides (MN) hundreds of metres below the Earth's surface. Muon paleotopometry is a novel method introduced at Dalhousie U., employing the pattern of MN concentrations along vertical (this experiment) and horizontal sampling transects (Soukup, 2018) to resolve topographic evolution and erosion history. The vertical method compares measured and computed MN concentrations at various muon-dominated depths (>3 m).The discrepancy between MN concentrations that build up in rock over millions of years and those computed using modern sample depths by physics-informed codes reveals changes in shielding, i.e., crustal erosion. To prove the concept, granite and quartz arenite from drill core are being collected at depths ranging from 0-3000 m near Sudbury, Canada. We hypothesize that the computed MN concentrations will be less than the measured ones due to the reduction in shielding over time, owing to fluvial and glacial erosion since the Miocene. 10Be and 26Al record the last ~8 and ~4 Myr, respectively, so we further hypothesize that the erosion rate determined from 26Al measurements will be faster than from 10Be. Initial computations have begun using MUTE, a code that amalgamates MCEQ and PROPOSAL to solve cascade equations and propagate particles underground while factoring in site-specific topography to obtain surface and depth-dependent muon fluxes. Folding the muon fluxes with nuclear cross sections (probability of a muon interacting with a target atom) in GEANT4 yields the MN production rates and concentration. Advantages of the muon paleotopometry method include simplifying the cosmic ray pathways down to one (fast muons interacting with quartz) and insensitivity to variations in the geomagnetic field due to the high particle energies needed to penetrate hundreds of metres.

Alireza Niksejel

Machine-Learning OBS Phase Picker – OBS Transformer and Its Preliminary Application to the Cascadia Subduction Zone

Alireza Niksejel, Miao Zhang

Cascadia stands out as one of the most intriguing subduction zones globally, renowned for hosting a significant megathrust earthquake (M ~9) in 1700, yet it has remained locked with minimal detectable seismic activity. To investigate the region's seismicity and deepen our understanding of its locking status, the quality and quantity of earthquake detection and localization are of paramount importance. Traditionally, seismic phase arrivals have been identified and picked by seismologists or automatic algorithms, resulting in substantial pick errors and numerous missed events, particularly for low-magnitude earthquakes or seismic events recorded in noisy environments like OBS (Ocean Bottom Seismometer) data. Recent strides in Machine Learning techniques show promise in automating land-based seismic phase picking. However, their application to OBS data has revealed notable limitations. Here, we adopt recent Artificial Intelligence innovations to develop OBSTransformer, a Machine Learning phase picker for OBS data, based on Transfer Learning and automated labeling. Extensive testing reveals that OBSTransformer exhibits reduced dependence on detection/picking thresholds and greater robustness to noise levels compared to its base model – EQTransformer. To investigate the Cascadia Subduction Zone, we apply the OBSTransformer to the two largest open OBS datasets for earthquake catalogue building, consisting of four-year seismic data recorded at 7D stations by the "Cascadia Initiative" project and one-month seismic data recorded at YR stations from the "Cascadia Seismic Imaging Experiment 2021" project. Preliminary tests yield promising results, demonstrating that the OBSTransformer excels at detecting more complete and accurate earthquakes in the Cascadia Subduction Zone. This success holds the potential to significantly advance our comprehension of its seismic activity and complex tectonics.

Anna Ryan

Hurricane transport of ocean-sourced microplastic in the North Atlantic

Anna Ryan, Vittorio Maselli

The atmosphere can transport large quantities of microplastics (MPs) and disperse them throughout the globe to locations inaccessible by many other transport mechanisms. Meteorological events, such as tropical cyclones, have been proven to pick up and transport particulate matter, however, how hurricanes influence the transport and deposition of atmospheric MPs is still poorly understood. In this study, we collected samples of atmospheric fallout from Hurricane Larry as it passed over Newfoundland, Canada in September 2021. During the storm peak, 1.13 x 10^5 particles per m^-2 day^-1 were deposited, with a decline in deposition after the storm passed. Back-trajectory modelling and polymer type analysis indicate that those MPs may have been ocean-sourced as the hurricane passed over the garbage patch of the North Atlantic Gyre. This study identifies for the first time the influence of North Atlantic hurricanes on the atmospheric transport of ocean-sourced MPs, providing new insight to one, potential key mechanism controlling remote terrestrial MPs occurrence.

Elahe Sirati

Investigation of Seismicity in the Lower Laurentian Fan Seismic Slope

Elahe Sirati, Miao Zhang, Mladen Nedimović, Alireza Niksejel, Alexandre Plourde, Graeme Cairns, Katie Bosman, John Thibodeau

In November 1929, the most catastrophic earthquake in eastern Canada occurred in the Laurentian Fan Seismic Slope, 250 kilometers south of Newfoundland. This event triggered a massive submarine landslide, resulting in a tsunami and claiming the lives of 28 individuals. Since then, a few seismic studies have been conducted using land stations to evaluate the tectonic regime in the region; however, a detailed understanding of its seismic nature remains elusive due to the lack of a dense network of seismic stations. In November 2021, 12 Ocean Bottom Seismometers (OBS) were strategically deployed in the lower Laurentian Fan Slope as part of the first long-term test of the National Facility for Seismological Investigations (https://www.nfsi.ca/). Only eight OBS stations were successfully recovered, and only three months of data were of sufficient quality to be used for analysis. OBS stations are often hindered by incorrect timing (i.e., clock drifts), yet precise absolute timing is a critical factor in many seismological studies, such as earthquake location. To overcome this issue, we first detect any clock drift for individual stations using the double-difference travel time analysis of teleseismic earthquakes. Then we adopt the Ambient Noise Cross-Correlation technique to quantify the clock drifts. Our analysis reveals that six stations did not experience obvious time drifts, but one station had a time stamp issue of 1051.5 seconds, and the other one had experienced a systematic time shift. Upon identification and correction of the aforementioned time errors, we employ the machine-learning-based OBS phase picker – OBSTransformer, and the LOC-FLOW package to detect and locate 18 earthquakes during the three-month deployment in the Lower Laurentian Fan Seismic Slope. The acquired results indicate that the lower Laurentian Fan Slope still exhibits moderate seismic activity, but a comprehensive understanding of the detailed tectonics and faulting mechanisms remains elusive, primarily due to the limited number of earthquakes recorded in such a short period.

Michael Powell

Behaviour of niobium and tantalum in felsic systems

Michael Powell

Niobium and tantalum are critical metals which are vital to advanced economies and for the green energy transition due to their use in high-strength steel alloys (Nb) and capacitors (Ta). Economic deposits of Ta are most often associated with peraluminous granites in the form of Li-Cs-Ta pegmatites. Concentrations of both Nb and Ta tend to increase over the crystallization history of such intrusions but the ratio of their concentrations (Nb/Ta) decreases, generally being ~10 in the least evolved regions and <1 in the most highly evolved rocks. This is unexpected given the chemical similarity of these metals which predicts identical partitioning behaviour. As such, the mechanism(s) leading to enrichment of both Nb and Ta, concurrent with a decrease in their concentration ratio, has been a source of controversy. Conventional explanations invoke the crystallization of biotite and Fe-Ti oxides which have been shown to have different partition coefficients for Nb and Ta in some contexts. However, models of crystallization using currently measured partition coefficients fail to reproduce the observed trend in whole-rock Nb/Ta. More recent studies have argued that a magmatic volatile phase (MVP) may play a crucial role in segregating the two metals as evidenced by significant enrichments of each metal in metasomatized mineral domains and in fluid inclusions. Countering this claim is the paucity of experimental evidence for the ability of an MVP to mobilize high field strength elements (HFSE) including Nb and Ta. Two experimental suites will be completed to resolve these controversies. First, experiments will be performed to determine MVP-melt partition coefficients for all HFSE to directly test the ability of a geologically relevant, Cl-bearing MVP to mobilize these elements in felsic systems. In the second suite of experiments the extent to which biotite can fractionate Nb from Ta in peraluminous systems will be determined, again through the derivation of partition coefficients. These experimental studies are being complemented by current work to comprehensively document the compositions and trace element contents of Fe-Ti oxides associated with biotite in the South Mountain Batholith. These data will allow for empirical estimates of biotite/ilmenite partition coefficients as well as empirical ilmenite/melt partition coefficients after the experimental biotite/melt coefficients are derived. Together, these projects will bolster our ability to: 1) model the distribution of HFSE in felsic systems, 2) parameterize the necessary PTX conditions for ore development, and 3) account for apparent discrepancies in Nb and Ta behaviour.

Alisa Yakimenko

Stability of hexavalent molybdenum fluoride complexes in hydrothermal solutions

Yakimenko Alisa

This study reports the measurements of the solubility of crystalline molybdenum trioxide, MoO_3, in HF at 25, 100, 150, and 200°C, mostly at pressures close to the saturated water vapor pressure. The results showed that MoO_3 solubility increases with HF concentration. The solubility data can be explained by the two dissolution reactions: $MoO_3(cr) + H_2O(l) \rightarrow H_2MoO_4(aq)$ $MoO_3(cr) + HF(aq) + H_2O = HMoO_3F(aq)$ (at HF concentration above 0.01 m). We determined Gibbs energies of $HMoO_3F(aq)$ according to experimental data. Also, we evaluated dissociation constants of this form at investigated temperatures and extrapolated them using the Ryzhenko-Bryzgalin equation. The pK values were 0.32 0.05; 0.43 0.16; 0.99 0.030; 0.66 0.14 at 25, 100, 150 and 200°C (saturated water vapour pressure). Based on the results of the calculations, the role of $HMoO_3F(aq)$ in hydrothermal solutions was evaluated.

Mohammed Rifkhan Mohammed Nayeem

A Study on the REE-Bearing Minerals in Snap Lake Kimberlite to Understand the Potential for REE Extraction from Kimberlite

M.N.M. Rifkhan, Yana Fedortchouk

Rare earth elements (REEs) have emerged as vital components in modern technologies, driven by their essential roles in various applications. However, extracting REEs from primary sources is costly and environmentally harmful. Secondary sources offer a chance to reduce reliance on primary deposits and enable sustainable REE recovery. Kimberlites, known for diamond mining, produce tailings that have been investigated for carbon capture. We propose exploring kimberlite tailings as untapped secondary sources of REEs, addressing both mining waste management and expanding the critical REE supply chain through sustainable practices. The objective of this research was to understand the fate of REEs in Snap Lake (SL) kimberlite after emplacement. Eighteen thin sections representing all six facies of hypabyssal kimberlite (HK) at SL were included in the study. Petrographic and scanning electron microscopes were used to study REE-bearing minerals, their structures, and textures. TiO_2 grains were further analyzed with micro-Raman to identify their polymorph. Four different types of monazites (Type 1-4), four different types of anatase (Type A-D), and two different types of apatite (Typei-ii) were observed. No perovskite was observed. All the TiO_2 observed showed a similar spectrum corresponding to anatase. Monazite and Type A anatase were identified as the primary carriers of REEs within the SL kimberlite. The predominant type of monazite observed in the Snap Lake kimberlite was Ce-monazite. The outer rim of the Type A is enriched in Nd, while La becomes more abundant toward the core region. The sample with Type 3 monazite in HK1 shows the highest concentration of REEs. In conclusion, perovskite was the original host of REEs, which is not preserved in SL. The alteration in a CO_2-rich weakly acidic hydrothermal environment has completely converted the perovskite to monazite and anatase. This results in the redistribution of REEs, with a high concentration in monazite (Type 1) and the remainder in REE-bearing anatase. Further, the alteration of anatase produces zoning with Nd enrichment in the core and La in the rim (Type A). Hence, monazite, as a phosphate mineral and the main host of REEs in SL, is more favorable for the extraction of REEs than perovskite.

Kathleen Clark

Using biotite and apatite to determine the petrogenesis of the Davis Lake Pluton, NS, Canada

Kathleen Clark, James Brenan

The South Mountain Batholith, located in southwestern Nova Scotia, Canada, is the largest granitic body emplaced during the Appalachian orogeny. Despite its large size, the SMB hosts only one significant Sn ore deposit near East Kemptville, NS. This deposit is associated with the Davis Lake Pluton (DLP), a smaller intrusion that is part of the South Mountain Batholith. Previous research has suggested that the Sn deposit formed as a result of extensive fractional crystallization, which enriched the magma that formed the DLP in Sn. This was followed by the exsolution of a F-rich magmatic vapour phase which transported and deposited the Sn, forming the ore deposit. However, this theory has never been tested through geochemical modelling. Thus, the purpose of this research is to geochemically model the formation of the DLP and the East Kemptville Sn deposit using the alphaMELTS thermodynamic software and geochemical data from two key minerals in the DLP, biotite and apatite. Initial modelling of the DLP biotites was done using simple fractional crystallization models, with the models providing different results depending on what the initial composition of the crystallizing magma was. Using the compositions of the least evolved biotites as the initial magma composition results in a model that reasonably agrees with the measured biotite data. However, using the whole-rock composition of the least evolved samples results in a model that vastly underestimates the concentrations of several elements of interest (Sn, W, and Li) in biotites. These models suggest that in situ crystallization of biotites lead to the measured trace element concentrations, and that the biotite compositions do not reflect the main liquid line of descent for the DLP. Future research will focus on trace element mapping of biotite grains, which is expected to provide more information on the in situ crystallization process. Once the effects of in situ crystallization are understood, the DLP liquid line of descent, and thus the evolution and formation of the ore deposit, can be modelled more accurately.

Peteris Rozenbaks

Redox-sensitive element partitioning between apatite, biotite, and glass in natural igneous rocks

Rozenbaks, P., Brenan, J.

In terrestrial igneous systems, several elements exist in multiple oxidation states (e.g., Fe2+ and Fe3+ of iron, V2+, V3+, V4+, V5+ of vanadium, Sn2+ and Sn4+ of tin, W4+ and W6+ of tungsten, Eu2+ and Eu3+ of europium etc.). The proportions of the oxidation states are controlled by the oxygen fugacity (fO2) of the system. Due to ionic charge and size differences, each oxidation state behaves differently during the mineral/melt partitioning. Apatite and biotite are ubiquitous minerals in a multitude of natural rocks. Both biotite and apatite mineral structures are capable of hosting a wide variety of elements, each mineral having a different set of compatible and incompatible elements. Given that the hosting capacity of these structures change depending on the physical parameters of the igneous system (including fO2), we expect to observe systematic changes in the elemental abundance in apatite, biotite, and coexisting melt, and the corresponding partition coefficient (D) values. In this study, we determine the elemental D values for partitioning between apatite, biotite, and glass in a suite of natural rocks. The suite includes Fish Canyon tuff (Colorado, US), Mascota minette (Jalisco, Mexico), Revancha rhyodacite (Peru), Toba tuff (Sumatra, Indonesia), Umiakovik granite (Newfoundland, Canada). The group comprises various compositions, emplacement depths, and oxidation states (previously determined range of FMQ-3.1 to +4.3 log, which represents the majority of oxidation states found in Earth's upper crust). The determined D values of multivalent elements show variations, in which fO2 is a major contributor. In particular, vanadium partition coefficient between apatite and biotite varies from ~0.002 to ~0.5 in a positive correlation with the fO2 over the represented redox range. This suggests that vanadium partitioning between apatite and biotite is a promising oxybarometer. Apatite-biotite oxybarometer could be applicable to iron-poor rocks such as peraluminous granitoids and carbonatites, which often lack Fe-Ti oxide minerals, necessary for the conventional oxybarometry methods. Vanadium partitioning systematics determined in the peraluminous South Mountain batholith, Nova Scotia (SMB; earlier study) and Palabora carbonatite, South Africa (this study) correspond with a relatively low oxidation in SMB and a high oxidation in Palabora. Since both SMB and Palabora carbonatite lack well-established fO2 estimates, this illustrates a potential field for a novel vanadium oxybarometer.

Tsz Kin Siu

Investigation of the Feedback Loop between Wildfire Occurrences and Regional Weather Patterns in the Long- and Short-Term Using Deep Learning and Remote Sensing Data

T.K. SIU & T. L. TAM

The advent of the deep learning techniques such as convolutional long-short term memory (ConvLSTM) in 2015 had marked a milestone enhancing the accuracy when modelling and predicting spatial and temporal data. For the problem of wildfire prediction, previous studies were having either high precision but low recall, or vice versa. While past research was mostly conducted over short term and small areas, this study would also seek the possibility for investigation of short-term and long-term feedback behaviours between the wildfire progression and its impacts to the changes of weather attributes. It would assess if the presence of wildfire features could help enhance weather forecast accuracy. The study focused on two target biomes: Montane Forest and Amazon Rainforest respectively over a large border. Overall, this study achieved a more balanced result in terms of F1-score for burned area detection based on past wildfire and weather patterns. Despite several limitations including computational resources for handling high-resolution data, relatively short project time spanning only half a year, and the compromise of reducing spatial resolution of the predicted output to cope with an extremely imbalanced ratio of fire pixels in the dataset, the bi-directional ConvLSTM structures with self-attention mechanism still had proven to be promising when modelling such tasks. In particular, short-term wildfire and weather predictions for the next day, as well as long-term monthly weather forecasts were found to be significantly better than the long-term fire event predictions. Further efforts might experiment with more complex models or ensemble models that could take into account domain knowledge, like Physics-informed neural networks, to improve the supervised training performance. Due to a large variation accumulated across months and possible non-natural factors affecting the site of burning, more data should be inputted into training, in order to develop a practically deployable machine learning solution for disaster or forestry management.

Lydia Fairhurst

On a Quest to Crystallise Titanite

L. Fairhurst, Y. Fedortchouk, I. Chinn, P. Normandeau and M. Powell

Kimberlites are diamond-bearing mantle-derived magmas with poorly constrained composition and emplacement processes. They typically form pipe-shaped structures and associated small intrusions, comprising various coherent (CK) and volcaniclastic (VK) units. Kimberlites transport mantle material, including diamonds and other mantle minerals, which react with the kimberlite melt to form various reaction products, including rims (coronae), zoning, and dissolution features. In my research, I focus on the interaction between ilmenite and chromite macrocrysts with the kimberlite magma. The initial project revealed that ilmenite macrocrysts exhibited coronae with distinct compositions in each unit for two kimberlite bodies in the Orapa cluster (Botswana). Notably, we observed different Ti-bearing phases, including magnetite + perovskite in CK and perovskite + titanite in VK. We proposed three factors that could induce conditions in VK favouring titanite stability, including: 1) Isobaric cooling of the kimberlite; and an increase in silica activity (a_{SiO_2}) caused by 2) assimilation of high SiO_2 (crustal) rocks and 3) reduced water content in the kimberlite magma. I conducted high-pressure temperature (1100-1200 °C, 0.5-1 GPa) experiments using a piston-cylinder apparatus to test these factors. These experiments successfully replicated the observed reaction coronae in natural samples, including the formation of magnetite + perovskite coronae in CK and perovskite + titanite coronae in VK. The presence of perovskite ($CaTiO_3$) and titanite ($CaTiSiO_5$) in the samples allowed me to constrain this reaction in P-T space and determine a_{SiO_2}, thereby shedding light on the varying crystallisation conditions and emplacement processes of kimberlites.

Chukwuka Orji

Exploring Nitrogen Cycling in Lagos Lagoon, Nigeria: First Steps Towards an Integrated Monitoring Program

Chukwuka Orji[a,b], Juliet Igbo[c], Akeem Abayomi[d], Owen Sherwood[a], Douglas W.R. Wallace[b]

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Abstract

Lagos Lagoon is a pivotal coastal ecosystem in West Africa which supports the livelihoods of millions while facing severe degradation attributed to dense human habitation in its watersheds. Despite escalating pollution threats associated with a large and rapidly growing population, the lagoon lacks a coordinated water quality monitoring program, exacerbating concerns over its deteriorating water quality and diminished ecosystem services. This study addresses this critical gap with an exploratory survey of nitrogen (N) cycling within Lagos Lagoon to establish a baseline N budget, leveraging stable isotope ratios of nitrogen ($\delta^{15}N$) within key bioindicators to discern sewage impacts and other nitrogen sources. Samples of fish, shrimp, crab, and macroalgae were systematically collected from four stations across the lagoon, and sediment from 10 stations, encompassing both densely populated and less inhabited regions. Samples were collected in dry (December) and rainy (August) reason. The excised muscles from the biota and sediments were freeze dried in Nigeria, shipped to Dalhousie University (Canada), ground, weighed, and analyzed. Through a new Nigeria-Canada collaboration using stable isotope analysis, this research aims to quantify the extent and magnitude of sewage impacts, thereby laying the foundation for an environmental monitoring program. The investigation has three main objectives: first, to delineate spatiotemporal variability of $\delta^{15}N$ across an urbanization gradient for the first time, providing insights into the nexus between population density and nitrogen cycling. Second, to employ a simplified two-end-member N budget to estimate the magnitude of sewage inputs into the lagoon. Finally, to evaluate the impacts on food web trophic structure as one traverses from highly impacted to less affected zones of the lagoon. The preliminary results show a gradient in $\delta^{15}N$ between highly urbanized and urbanized areas of the lagoon. The presentation will present results from both dry and rainy seasons and evaluate lessons learned concerning sampling, logistics and other requirements of a monitoring program.

Keywords: Lagos Lagoon, nitrogen cycling, stable isotope analysis, sewage impacts, environmental monitoring, coastal ecosystem.

Marina Dottore Stagna

Pliocene graben development led the reorganization of the deep-water sediment routing systems offshore Tanzania

Marina Dottore Stagna, Vittorio Maselli, David Reynolds, Djordje Grujic, David Iacopini

The East African Rift System (EARS) spans thousands of kilometers from Ethiopia to Mozambique and, in Tanzania, it bifurcates into two main branches (namely the Western and Eastern branches). In the offshore domain, previous studies have unveiled the possibility of the offshore continuation of the Eastern branch along the Tanzania and Mozambique margin. Yet, the distribution and timing of the extensional features along the Tanzania margin and their influence on sediment deposition remain poorly constrained. In this study, we investigate a portion of the continental slope offshore Mafia Island, located off the coast of Tanzania, where 2D and 3D seismic reflection data and an exploration well have been collected by the energy industry. In this area, the seafloor exhibits a previously unidentified NNW-SSE-oriented graben which is currently being infilled by a sinuous turbidite channel. We hypothesize that the opening of this graben resulted in a net reconfiguration of the submarine channel network, altering the eastward sediment delivery dynamics that controlled the deep-water depositional system along the margin for millions of years. Our main goal is to investigate the genesis of this structure and its impact on the evolution of slope channel systems over time, to provide new constraints on the structural and stratigraphic evolution of the margin. By quantifying the timing of faults activity and examining changes in kinematics, we also aim to determine whether the origin of this graben is linked to the tectonics of the EARS, thus providing new evidence for explaining the extensional tectonics along the margin.

INVESTIGATING SOURCES AND ALTERATION OF SEDIMENTARY ORGANIC NITROGEN ISOTOPE SIGNALS USING CSIA-AA

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Interpreting paleoceanographic records preserved in sedimentary organic material requires a fundamental understanding of the geochemical transformations that particulate organic matter (POM) undergoes from production in surface waters to deposition on the seafloor. Often this transit of POM is complicated by protracted resuspension-deposition cycles, facilitated by bottom currents, which pre-ages organic matter before ultimate burial. The resulting impacts of pre-aging on the preservation of organic geochemical proxies, including N isotopes, remains relatively unexplored. We used compound-specific N isotope analysis of amino acids ($^{15}N_{AA}$) to track the relative proportions of different sources (phytoplankton, zooplankton and fecal pellets) contributing to POM export, and to assess the pathways and magnitude of microbial alteration in surface sediments from different oceanographic regions. Preliminary results indicate that the balance of animal versus plant sources to POM export is highly dependent on location. In the Gulf of Maine, animal sources comprise most (>75%) of the sinking POM collected in the 150m-deep sediment traps. However, the 250m-deep traps and in underlying sediments, the POM is highly attenuated with respect to organic content and exhibits a completely different $^{15}N_{AA}$ signature consistent with microbial reprocessing in a permanent benthic nepheloid layer. These results raise important considerations for interpreting N isotopic and other organic geochemical proxy records in sediment paleo-archives.