TRAPPED IN THE ICE: AN ANALYSIS OF BRINES IN BRITISH COLUMBIA'S HYPERSALINE LAKES

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Introduction: Ice-ocean worlds are promising candidates in the search for habitable environments beyond Earth. Of particular interest is the boundary between ice and underlying oceans/brines, as this interface sustains a rich biosphere in analogous terrestrial environments [1-3]. As we are currently unable to directly measure these locales on icy worlds, it is highly informative to understand how biogeochemical processes function under different pressures and across different thermal and chemical regimes in analogous ice-ocean/ brine environments on Earth.

An important feature of terrestrial ice-brine interfaces is their multiphase nature. When saltwater freezes, the salt is rejected from the crystalline ice structure, creating pockets and channels of concentrated brine in which microbes thrive [2, 3]. The chemical composition of these concentrated brines govern biologically relevant system properties, such as pH, water activity, and chao-/kosmotropicity [4, 5]. These combined chemical and physical processes dictate how well brines can entrain and sustain biosignatures. Biogeochemical analysis of terrestrial analogs can be used to inform predictive models of ice-ocean/brine system evolution on other ice-ocean worlds (e.g. remnant/relict Martian ice-brine systems [6], perched water bodies within the ice shell of Europa [1, 7]).

An exceptional testing ground for understanding ice/brine dynamics is the hypersaline lakes of the Cariboo plateau in central British Columbia [8, 9]. These lakes span a large range of salinities ((0-350 g/L) [8]) and have diverse chemistries ($MgSO_4$, $NaCO_3$) which may better reflect the chemistry of icy world oceans and Martian brines than does our own ocean's composition [6, 10]. This drastic variability provides a natural laboratory to investigate how thermochemical and environmental pressures affect biosignature distribution within and biogeochemical evolution of uniquely relevant analog systems.

Here, we present the first chemical and biological profiles for the ice cover of these lakes. We introduce a multiphase reactive transport model capable of simulating the evolution of these systems and compare simulated ice chemistries to the measured profiles. We highlight the implications this work has for quantifying ice-ocean world habitability and discuss recent summer and winter fieldwork.

Biogeochemical Profiles: In February 2019, ice samples from three lakes (Salt Lake [51°04'27.7"N 121°35'05.4"W], Last Chance Lake [51°19'39.7"N, 121°38'01.7"W], and Basque Lake [50°36'00.0"N, 121°21'30.9"W]) were taken at progressive depths for biogeochemical analysis (ion chromatography (IC), cell counts). IC provides the concentrations of anions in the samples, while Flame Atomic Absorption Spectroscopy (Flame AAS) was used to determine the concentrations of cations [Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}]. Examples of the ionic profiles can be seen in Figures 1-3. Bioburden profiles were acquired by filtering samples, staining the filters with 4′,6-diamidino-2-phenylindole (DAPI), and counting the number of cells present using fluorescence microscopy and ImageJ software.

Numerical Model: We have modified the one-dimensional multiphase reactive transport model of *Buffo et al.*, 2018, which simulated the physical and thermochemical evolution of sea ice, to accommodate the diverse chemistries of the British Columbia lakes. We simulate the seasonal top-down solidification of the lakes and produce ionic profiles which can be compared to those acquired in the field. Validation of the model's ability to reproduce the observed chemical profiles in these unique terrestrial analog systems bolsters its utility as a tool for assessing the thermochemical evolution of planetary ice-brine environments.

Recent Field Work: During fieldwork in September 2019, lake samples were collected, HOBO temperature sensors were installed (data loggers), and a scientific camera was placed alongside each of the observed lakes. To obtain a temperature profile of these systems, one HOBO data logger was positioned directly above the sediment layer of the pools, and another was placed right below the surface at each of the sampled lakes. In addition, one logger was attached to the scientific cameras to collect air temperatures surrounding the lakes. Fieldwork in February 2020 will consist of further ice/brine sampling, the recovering of HOBO temperature sensors, and a geophysical survey to characterize the conductivity structure underneath the ice.

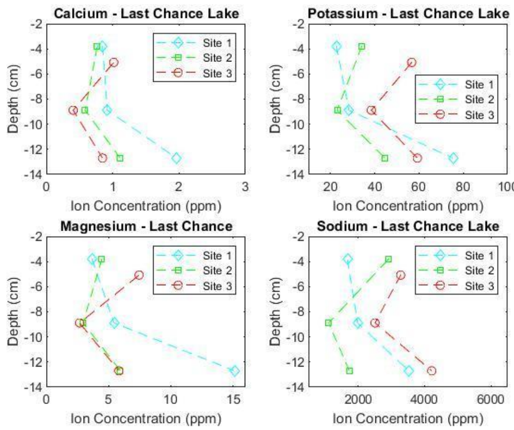

Figure 1: Cation profiles for Last Chance lake. All sites exhibit a 'c-shaped' profile, similar to the characteristic bulk salinity profiles of first year sea ice.

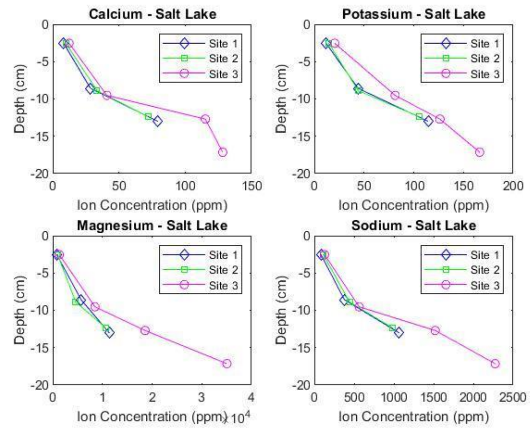

Figure 2: Cation profiles of Salt Lake. Ion concentrations increase with depth, suggesting drainage of the concentrated interstitial brine.

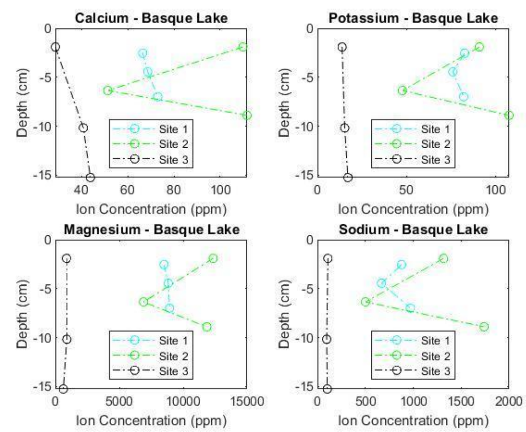

Figure 3: Cation profiles of Basque Lake.

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