

Thermokarst lakes are an important part of the global carbon cycle, releasing an estimated $24.2 \pm 10.5 \text{ Tg CH}_4 \text{ yr}^{-1}$ into the atmosphere (Walter et al. 2007). Recent research indicates the potential of thermokarst lakes as sites of significant carbon burial. I will conduct high-resolution analysis of thermokarst lake cores and a drained thermokarst lake basin permafrost core, to enable the assessment of variations in carbon burial through the evolution of a thermokarst lake and through the thermokarst lake cycle. I will use a combination of proxies including stable isotopes ^{15}N and ^{13}C , and percentage of total organic carbon, to analyze the relationship between lake development, carbon sources and the amount of carbon burial.

Beringian thermokarst lakes develop within carbon and nutrient rich yedoma. Yedoma deposits cover 10^6 km^2 of Beringia and formed through the deposition of wind blown silt during the Late Pleistocene, between 80 and 12 kyr BP (Schirmer et al. 2008). As sediment accumulated, organic detritus from the mesic steppe tundra were buried and frozen by aggrading permafrost. Syngenetic ice wedges formed, producing a landscape vulnerable to thermokarsting in the warmer climate that was established at the Pleistocene - Holocene boundary (Walter et al. 2007b). As a result of the burial and freezing of Pleistocene plant remains, yedoma soils are nutrient rich compared to other arctic soils. In the phosphorus limited environment of the Arctic, the high phosphorus content of yedoma, (weighted average of 20-38 mg $\text{P}_2\text{O}_5/100\text{g}$ for modern soils (Davidov, pers. comm.)), is a valuable source of nutrients. This nutrients is mobilized upon the thaw of yedoma sediments which is currently occurring widely in the form of thermokarst development across Beringia.

Lakes in the Arctic are generally reported to be ultraoligotrophic (Bonilla et al. 2005). This is due to a combination of low temperatures, the presence of permafrost restricting nutrient mobilization, and limited nitrogen and phosphorus in arctic soils (Prentki 1980, Pienitz 1997, Bonilla et al. 2005). High nutrient levels of yedoma may make Beringian thermokarst lakes a potential anomaly to this rule. I hypothesize that this nutrients is mobilized as thermokarst lakes develop in yedoma areas, causing high lake productivity, including plant growth, resulting in high carbon burial.

Thermokarst lakes form through the thaw and collapse of the syngenetic ice wedges within yedoma (French 2007). Once initiation has occurred, thermokarst lakes evolve from small ponds by expanding from a central point through the thaw and collapse of their lake margins (Hopkins and Kidd 1988). As lake evolution continues, lake sediments accumulate, burying carbon present from either in-washed terrestrial material or in situ aquatic plants. Due to the high nutrient content of yedoma sediments, the amount of productivity and carbon burial is expected to be higher than non-yedoma arctic lakes. Studies of extant thaw ponds in the Canadian high arctic indicate that thawing sediments are releasing nutrients previously locked up in surrounding permafrost resulting in high productivity (Breton et al. 2009). Recent studies of Pleistocene rivers in the Cherskii region in western Beringia (Finlay et al. in prep), illustrate that high phosphorus levels entering rivers from eroded yedoma material have a fertilizing effect, resulting in high aquatic productivity. Currently no literature exists investigating high levels of productivity and high levels of carbon burial as thermokarst lakes development. It is important to identify the amount of carbon burial that is occurring in thermokarst lake sediments, to understand more fully their role in the global carbon budget.

Thermokarst lakes drain when expansion causes margins to erode into a drop in elevation, or river system. Once drainage occurs, ice wedge formation begins and lake initiation can occur once again, through ice thaw and sediment collapse, within a drained thermokarst lake basin (Billings and Peterson 1980). Thermokarst lake formation began on the northwest Seward Peninsula $\sim 14\text{kyr BP}$ (Walter et al. 2007b) and as a result, the landscape is characterized by thermokarst lakes and alases of different generations and ages. I will use a combination of lake and permafrost cores to assess variation in carbon burial between thermokarst lake generations. I wish to apply for funding from the Dave and Rachel Hopkins Fellowship for permafrost core sub-sample analysis from a second generation thermokarst lake. This will enable a comparison to be made between carbon burial in two other extant thermokarst lakes.

My study sites are located on the coastal lowlands of the Seward Peninsula in north-west Alaska. This is a region of extensive thermokarst and thermokarst lake development. Much of the landscape is

modified by different generations of thermokarst lake and drained thermokarst lake basins. I have chosen one first generation extant lake, Claudi, one third generation extant lake, Rhonda and one second generation drained thermokarst lake basin, Mama Rhonda (Figure 1). These study lakes will enable me to analyze any changes in carbon burial that occur through the evolution of a thermokarst lake and through the thermokarst lake cycle, between lake generations.

To establish how carbon burial changes through the evolution of a thermokarst lake it is firstly necessary to understand the sedimentology of my study thermokarst lakes and secondly identify sediments that represent different stages of thermokarst lake development. Using a combination of my own data and existing literature (Czudek and Demek 1970, Hopkins and Kidd 1988), I have identified six key sediment units and their distribution within and below a thermokarst lake basin. Figure 2 illustrates the final stage of a sediment unit distribution for a mature thermokarst lake.

Using my knowledge of thermokarst lake evolution and thermokarst lake sediment units, I have selected sub samples from a number of sediment units in Lake Rhonda and Lake Cladudi. Each sediment unit represents a different stage of lake formation, therefore analysis will enable me to interpret changes in carbon burial through lake development. I have selected 46 sub samples from two sediment units within Lake Rhonda and 89 sub samples from three different sediment units within Lake Claudi. Through combining analysis of the Mama Rhonda permafrost core, with lake cores from Lake Cladui and Lake Rhonda, I will identify key differences in levels of carbon burial between a first, second and third generation lake.

I will analyze sub samples taken down through lake and permafrost cores for percent total organic carbon (percent C_{org}), stable isotope analysis ^{15}N and ^{13}C and biogenic silica levels. Additional proxies include macrofossil and smear slide analysis. percent C_{org} will provide a proxy for the amount of carbon burial occurring within each sediment unit. Stable isotope analysis of total $\delta^{15}N$ will identify proportions of algal and land-plant organic matter and both $\delta^{15}N$ and $\delta^{13}C$ will provide evidence for enhanced algal productivity (Meyers, 2003). This will enable me to identify whether yedoma is causing high levels of productivity and carbon burial within my study thermokarst lakes. Down-core variations in biogenic silica, a chemical estimate of the siliceous microfossil abundance, will be used as a proxy for changes in lake productivity (PALE 1994). I am requesting funding from the Dave and Rachel Hopkins Fellowship to enable biogenic silica analysis at the LacCore Facility, and percent C_{org} and stable isotope analysis of $\delta^{15}N$ and $\delta^{13}C$ at the Alaska Stable Isotope Facility for 35 sub samples that have been selected from the Mama Rhonda permafrost core. To date, all lake core samples have been submitted for analysis.

Once I receive my results, I will combine both my understanding of thermokarst lake sedimentology with results from the aforementioned proxies to better understand how paleoproductivity is related to basin evolution and thermokarst lake cycling.



Figure 1. Location of study sites. Lake cores have been obtained from Lake Rhonda and Lake Claudi. Permafrost cores have been obtained from drained thermokarst lake basin Mama Rhonda.

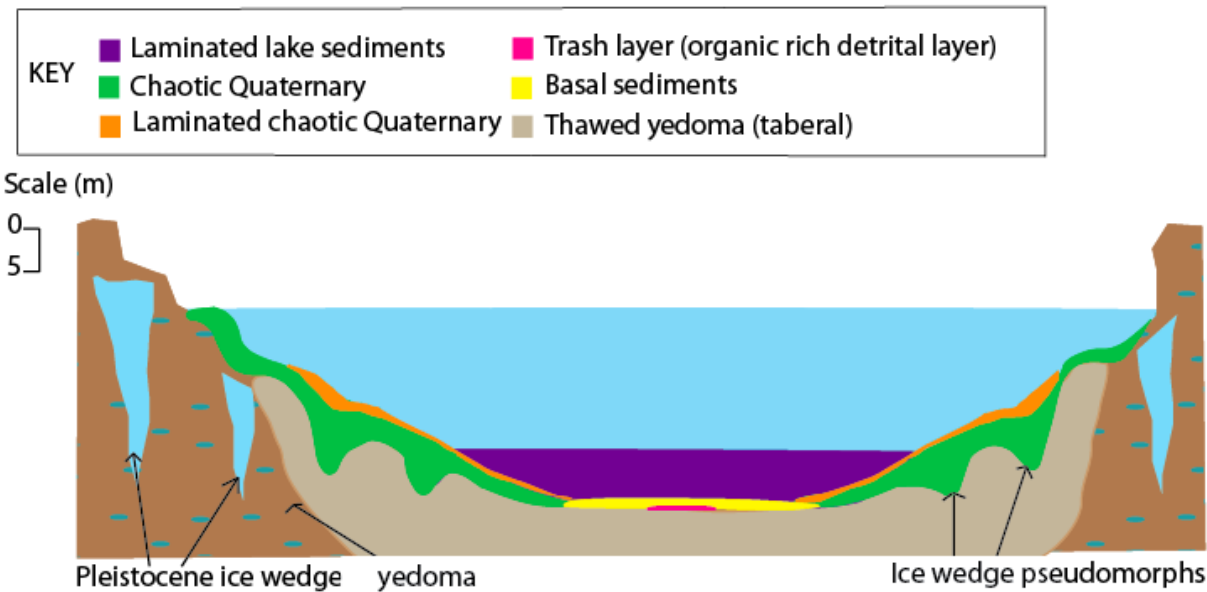


Figure 2. Thermokarst lake sediment units present in a mature thermokarst lake basin. For the purpose of this study laminated lake sediments, chaotic Quaternary sediments and laminated chaotic Quaternary sediments will be analyzed.

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Permit	
Research on Federal, State, and some private land may require a permit.	
Do you (or your advisor) have the required permit for your proposed research?	Y N
<p>If you do not have the required permit:</p> <ul style="list-style-type: none"> • Provide the name of the issuing agency and person in charge of permitting (and their contact info.). • Describe at what stage you are in the permitting process (i.e., the application is submitted, but no response, or you have a verbal assent, but not in writing, etc.), and the likelihood that you will receive the permit. • <i>Applicants that have not started the permitting process at the time of proposal submission may be at a disadvantage during proposal evaluation.</i> 	
<p>Agency:</p> <p>Agency contact person and their contact information (phone and/or e-mail address):</p> <p>Stage of the permitting process and likelihood of receiving the permit:</p>	

Budget

Analysis	Cost	No. of samples	Funding source	Total
Permafrost core biogenic silica	\$18 per sample	35	AQC	\$ 630
Permafrost core stable isotope analysis for ^{13}C and ^{15}N	\$16 per sample	35	AQC	\$ 560
Permafrost core percent C_{org}	Included in isotope analysis	\$0	N/A	\$0
Lake core biogenic silica	\$18 per sample	135	NSF	\$2430
Lake core stable isotope analysis for ^{13}C and ^{15}N	\$16 per sample	135	NSF	\$2160
Lake core percent C_{org}	Included in isotope analysis	\$0	N/A	\$0
			Total:	\$5,780
			Amount requested from AQC	\$1,190

Budget Justification (use as much space as needed): Biogenic silica samples will be submitted to the LacCore facility, University of Minnesota. Stable isotope samples will be prepared and weighed by myself and submitted to the Alaska Stable Isotope Facility at UAF.