A Paleolimnological Study of Two Lakes in Jasper National Park, Alberta

By

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ABSTRACT

Two 5-m sediment cores from Little Trefoil Lake, and one 1-m sediment core from Dead Man's Hole, Jasper, Alberta were retrieved and analyzed to determine diatom productivity based on the weighted percentage biogenic silica. The cores were sub-sampled at 10 cm intervals and were analyzed for biogenic silica, an estimate of siliceous algal production. Samples prepared for diatom analysis were qualitatively evaluated; biogenic silica concentrations in Dead Man's Hole were low (between 0.8% and 6.8% of the sample weight), and this was supported by low abundances of diatoms and Chrysophyte cysts. Therefore, further analysis of Dead Man's Hole was not made, including dating. Little Trefoil Lake sediments were characterized by well- preserved diatoms and low to moderate concentrations of biogenic silica (1.7% to 12.8% of the sample weight in core 1 and 3.1% to 11.9% of the sample weight in core 2). Chronology for the Little Trefoil Lake core was determined using ^{210}Pb dates and preliminary tephra dates. Results from this research show that biogenic silica is an indicator of changing productivity of diatoms and Chrysophytes in these Jasper Lakes. Although more research is required, initial analyses of the biogenic silica records appear to be linked to warmer temperatures during the medieval warming period.

Keywords: Jasper National Park, Alberta, biogenic silica, diatoms, Chrysophyte cysts, paleolimnology

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I would also like to thank Erika Hill for helping me carry out the numerous experiments necessary to complete this project to its full potential. Her constant support with all laboratory work was much appreciated. I also wish to thank Ed Eastaugh for the use of his laboratory; he was very understanding of my situation and was kind enough to put my schedule before his own. Thanks to Beth Hundey, Oliver Squire, and Kelly Hollingshead who were all very welcoming and provided me with support, laughter and camaraderie during my time in the lab. It was a time never to be forgotten.

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

APPENDIX

CHAPTER 1

INTRODUCTION

The Alberta and British Columbia landscapes are changing rapidly as a result of development, particularly logging and mining activities (Tande, 1979). There are six major anthropogenic periods of the Athabasca river valley in which Jasper National Park is located. These are: 1) Pre-European period, 10,000BP - 1800, 2) Fur Trade period, 1800 - 1830, 3) Pre-settlement period, 1830 - 1892 , 4) Settlement period, 1892 - 1910 , 5) Railroad period, 1909 - 1912 , and 6) Park period, 1913 – 1975 (and continuing to present) (Tande, 1979). The later five stages (stages in which development occurred) occur within a 200-year window and show how quickly changes to the landscape have occurred (Tande, 1979). These changes largely involve road construction and land clearing, as well as resulting pollution (Tande, 1979). It is expected that land clearance results in a transport of nutrients from the landscape to aquatic ecosystems (Likens and Bormann, 1974), which would result in an increase in aquatic productivity. Increased delivery of nutrients to aquatic systems can also occur with natural land clearance from, for example, from fire (Bradbury et al., 2004). In Jasper National Park there has been a policy to supress fires (Parks Canada, 2009), so this may have resulted in a change in nutrient inputs to aquatic systems over time. With fire suppression one might expect to see fewer, but more severe fires, which might result in an increase in nutrients for a given fire, but less frequent inputs.

To evaluate recent changes in nutrient concentrations in lakes it is critical to have knowledge of baseline conditions, which are not available because monitoring is temporally and spatially limited. The overall goal of my thesis project is to determine changes in lake production over the Holocene (last 10,000 years) in Jasper National Park, Alberta using biogenic silica, a measure of silica produced mainly by diatoms and Chrysophytes (Conley, 1988).

Paleolimnology

Paleolimnology is the study of aquatic ecosystems; it uses biological, chemical and physical information preserved in lake sediments to reconstruct environmental conditions from the past (Smol, 2008). One proxy that is easy to measure and often used in paleolimnological studies is biogenic silica; this is a measure of the amorphous silica content in sediments and is a good proxy for showing diatom abundance and diatom productivity (Conley and Shelske, 2001).

Biogenic Silica, Diatoms and Chrysophytes

Biogenic silica is silica produced from siliceous microfossils, particularly diatoms and chrysophytes (Conley and Schelske, 2001). Biogenic silica is commonly used in studies related to eutrophication, hydrological changes, and regional climate change (Conley and Schelske, 2001). Most importantly the amount of biogenic silica in sediment samples is shown to be a good representation of diatom abundance and other siliceous microfossils (Conley and Schelske, 1993). Biogenic silica can be measured using five different techniques; however, the easiest and most reliable are

the wet alkaline techniques (DeMaster 1979, 1981; Conley and Schelske, 2001). The wet alkaline technique involves determining the total dissolved silica (which is composed of both biogenic silica and mineral silica) and determining the point at which only biogenic silica is being dissolved. Biogenic silica dissolves at a much faster rate than that of mineral silica; the amount of silica from biological sources can be calculated as the Y-intercept when time is equal to 0. Two algal groups have siliceous components that contribute to overall biogenic silica in lakes – diatoms and chrysophytes.

Diatoms are single- celled algae that are characterized by their siliceous cell walls. Diatoms are taxonomically unique and can be identified to species or even sub-species level (Moser 2004). They are widespread being found in almost all aquatic environments that have sufficient light (Patrick, 1977). Individual diatom species have specific ecological requirements, and the distribution of diatom species can be used to infer past environmental conditions (Batterbee et al., 1999). Diatom community composition and populations change in response to changing environmental conditions. In particular, diatoms respond to changes in temperature, light, turbulence, and ice cover and chemical factors including, nutrients, pH, dissolved organic carbon, and salinity (Battarbee et al., 2001). With respect to nutrient concentrations, diatom productivity increases and species diversity decreases with greater nutrient concentrations (Battarbee et al., 2001).

Chrysophytes are algae that exist mainly as single celled organisms. Chrysophytes are preserved in the sediment record of lakes, rivers and ponds in two

forms: 1) scales, 2) stomatocysts, also referred to as cysts (Zeeb and Smol, 2001). Scales occur in two common genera *Mallomonas* and *Synura* (Zeeb and Smol, 2001). The *Mallomonas* scales are larger, more heavily calcified, and have a complex morphology in comparison to *Synura* scales (Zeeb and Smol 2001). Chrysophyte cysts are extremely abundant in oligotrophic and soft water lakes (Zeeb and Smol, 2001). Chrysophyte cysts are a siliceous resting stage of chrysophyte algae (Zeeb and Smol, 2001)

Chrysopyhtes can be found in many different limnological environments but are most commonly found in acidic or nutrient-poor lakes and are rarely found in alkaline or eutrophic lakes, however, exceptions do occur (Zeeb and Smol, 2001). Chrysophytes are useful for paleoenvironmenal reconstruction as the different taxa possess well defined environmental tolerances and optima (Zeeb and Smol, 2001).

Objectives

My overall research goal will use biogenic silica to track changes in lake productivity over the Holocene; with particular attention to the last 7500 years in Jasper National Park, Alberta using biogenic silica measured using the wet alkali technique (Conley, 2001).

The three main objectives of this thesis are:

1) To determine whether the biogenic silica measurement procedures developed in the Lake and Reservoir Systems (LARS) Research Facility provide reproducible measures.

2) To test the feasibility of using diatoms to track lake production overtime in Jasper National Park. . Diatoms are siliceous microfossils and being composed of silica are generally well-preserved, but recent research has shown that in the Canadian Rockies diatoms can be poorly preserved (Hobbs et al., 2010). Diatom sample preparation and analyses is extremely time consuming, but by using biogenic silica it is possible to rapidly assess the preservation of diatoms and determine whether they can be used to reconstruct past environments in Jasper National Park.

3) Determine changes in lake production overtime and speculate about what could be driving these changes.

CHAPTER 2

STUDY AREA

Jasper Alberta

The two study lakes are in Jasper, Alberta, Canada, which is a small town located in Jasper National park. The park lies in the middle of the Canadian Rocky Mountain range. The geology of the area can be divided into two distinct groups; the Front Range and the Main Range. The Front Range is composed mainly of Devonian to Paleocene limestones, sandstones and shales (Mountjoy, 1964). The Main Range is composed of Precambrian and lower Paleozoic shales and quartzites. Climate in Jasper is classified as subarctic, but is also similar to a humid continental climate (Environment Canada, 2009). The average summer temperature is 14.1 °C, and the average winter temperature in Jasper is 8.4 °C. Annual precipitation in Jasper is 398.7 cm, with the highest amount of precipitation 60.1 cm occurring in July (Environment Canada, 2009). Vegetation in Jasper is comprised of coniferous forests and includes: *Picea glauca* (White Spruce), *Picea mariana* (Black Spruce), *Pseudotsuga menziesii var. glauca* (Rocky Mountain Douglas-fir), *Populus tremuloides* (Trembling Aspen), and *Pinus contorta* (Lodgepole Pine). Prior to the creation of the park much of the land that is now Jasper National Park was open parkland due to the occurrence of forest fires (Tande, 1977). With the development of the park, fires have been suppressed, changing the landscape and vegetation of the park. Most of

the forests in the area grew following major fires that occurred in 1889, 1847, and 1758, which were also years of drought (Tande, 1977).

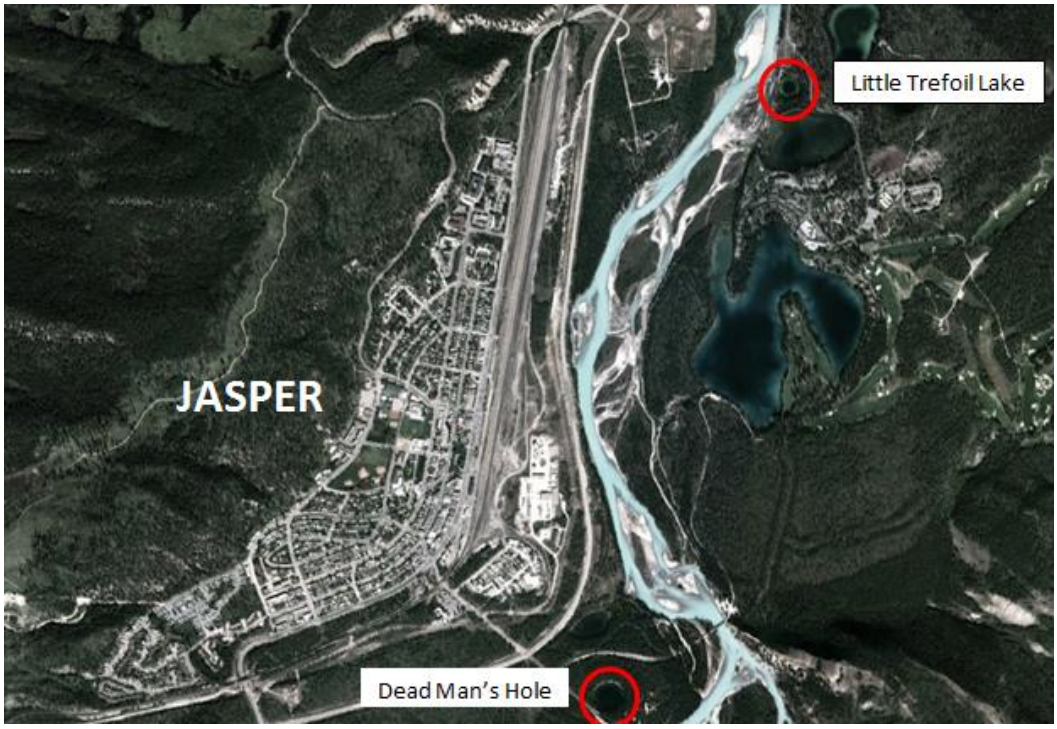

Figure 1: Jasper, Alberta 52°52'23"N 118°04'56"W Elevation 1062 m. Red circles indicate the two study sites, Little Trefoil Lake and Dead Man's Hole (Google Earth Image).

Dead Man's Hole

Figure 2 – Dead Man's Hole in summer. The green-blue colour of the water is likely due to the presence of $CaCO_3$ (Photo credit: Mike Kenigsberg, 2008).

Dead Man's Hole is located on the southeast boundary of Jasper, Alberta and 370 m to the west of the Athabasca River (Figure 1). The lake has a depth of 11.6 meters and has an area of 2.5 ha. The lake is situated in glacial till and is underlain by Paleozoic shales, limestones, and sandstones (Prince and Mountjoy, 1970). The water colour of Dead Man's Hole is an emerald jade, most likely due to the presence of silt and/or CaCO3 (Figure 2) (Wetzel, 2001). The vegetation surrounding the lake consists of *Pseudotsuga menziesii var. glauca* (Rocky Mountain Douglas-fir) (Figure 2 and 3). Submerged macrophytes were noted in the littoral zone, as well as submerged trees.

Figure 3: Dead Man's Hole (shown in winter) 52°52'01.8"N 118°4'14.7"W Elevation 1000 m. (Photo Credit: Roanne English, 2007)

Little Trefoil Lake

Figure 4: Little Trefoil Lake in summer displaying green water colour and surrounding vegetation. (Photo Credit: Mike Kenigsberg, 2008)

Little Trefoil Lake is located to the northeast of Jasper, Alberta and 5 m to the east of the Athabasca River (Figure 1). The lake has a depth of 5.2 meters and has an area of 2 ha. The lake is situated in glacial till, which is underlain by Paleozoic shale, limestone, and sandstone (Prince and Mountjoy, 1970). Vegetation in the littoral area includes sedges, grasses and other macrophytes (Figure 4), and the surrounding arboreal vegetation is mainly Douglas fir trees (Figure 5). The lake was stocked with fish from middle to late 1900's.

Figure 5: Little Trefoil Lake (shown in winter) 52°53’31.9”N 118°3’33.4”W Elevation 1023 m. (Photo Credit: Roanne English, 2007)

CHAPTER 3

METHODS

Field Methods

A team from the LARS Research Facility visited both sites twice – once in Feb. 2007 for sediment coring and once in July 2008 to collect water samples and make limnological measurements. The sediment samples used in this project were collected in winter in order to use the ice as a platform to work from.

Gravity Coring

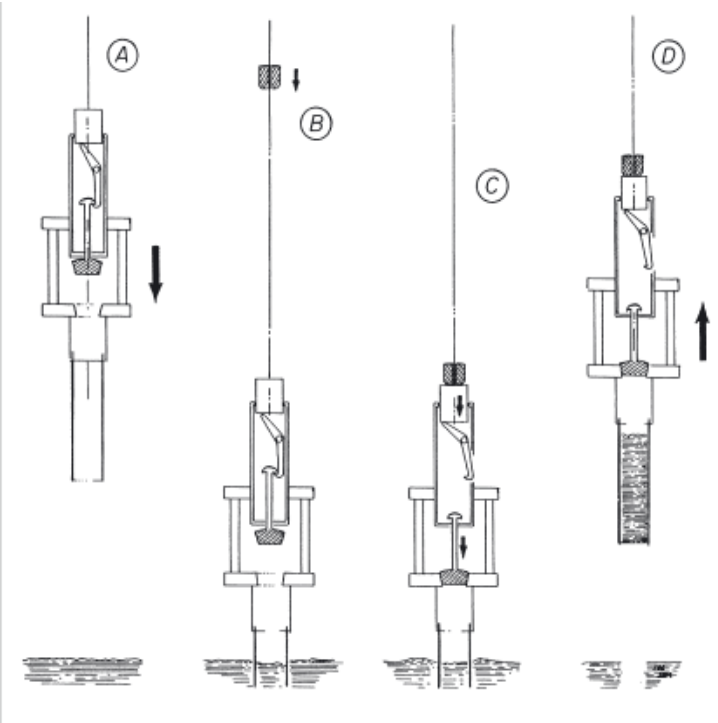

Figure 6: Operation of a KB gravity corer. (A) Corer lowered through water, (B) Corer enters the sediment, once in place trigger is released at the surface, (C) the trigger hits the corer and creates a seal, (D) corere is removed from the water (important to keep corer vertical upon removal from water) (Smol, 2002)

The upper 46 cm and 45 cm of sediment from Dead Man and Little Trefoil Lake, respectively, were collected using a Kajak-Brinkhurst (KB) open barrel gravity corer (Figure 6) (Glew et al., 2001). The corer is fitted with a 60cm long plexiglass tube (diameter is 6.5 cm). The whole device is attached to a rope and is slowly lowered into the water. In soft sediments, such as those at Little Trefoil Lake, careful attention needs to be paid so that only the core tube, and not the corer itself, enters the sediment. This ensures an intact sediment water interface. From the surface, a brass weight glides down the rope and triggers a plunger, which forms a seal at the top of the tube allowing for full recovery of intact sediments. Sediments were sectioned at 0.5cm intervals in the field using a Glew extruder (Glew et al., 2001). Sediment samples were placed in labelled whirl-packs and kept cold with snow in coolers until they were returned to the lab and refrigerated at 4°C.

Long Coring

Long cores were retrieved using a modified Livingstone corer (Figure 7) (Glew et al., Smol, 2008). Samples were taken in 1m overlapping sections. A total of ~ 10m of sediments (2 sediment cores spanning ~5m depth) were collected from Little Trefoil Lake. Only one 1 m core was collected from Dead Man's hole. The cores were extruded in the field, wrapped in plastic wrap and then aluminum foil and shipped back to the lab.

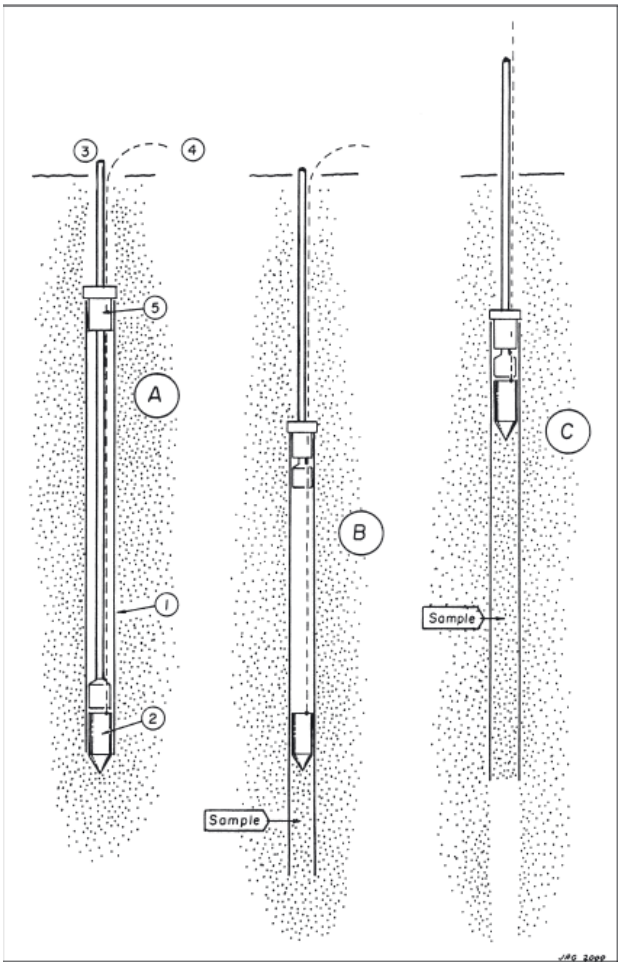

Figure 7: Operation of a Livingstone-piston corer. (A) Lowering phase, (B) Sampling phase, (C) Removal phase. (1) Core Tube, (2) Piston, (3) Drive rod, (4) Piston Cable, (5) Locking drive head. The drive rod is used to push the corer into the sediment, the cable is used to keep the corer in place. (Glew et al., 2001; Smol, 2008)

Limnological Measurements and Water Sampling

Water samples were taken in the summer of 2007 to determine current water quality. Water samples were taken in Nalgene bottles that were pre-cleaned. Each bottle was rinsed four times with ultrapure water and then rinsed three times with lake water in the field. The bottle was submersed to about 0.5m and filled full with no air bubbles, capped underwater and taped shut for further analysis to be

completed back in the lab. Samples were kept on ice and frozen as soon as possible. Water chemistry was determined at Canada Center for Inland Waters CCIW in Burlington, Ontario where they were processed to determine major ions, metal and nutrient concentrations.

Measurements of water temperature, pH, specific conductivity, and dissolved oxygen were taken with a multi-parameter Hydrolab DS5. Measurements were taken from the deepest spot in the lake and were recorded continuously at 0.2 m intervals.

Laboratory Methods

Core Descriptions and Sampling

Gravity core samples were weighed as soon as they were returned to the lab from the field. Total wet weight of each sediment sample is required for ^{210}Pb analyses. For the Livingstone cores, sediment descriptions were made and the cores were photographed using a 105mm 1:2.8 DG Macro EX SIGMA camera attached to a GSI multi-sensor core logger. Samples were taken every 10cm for Little Trefoil Lake and every 5cm for Dead Man's Hole for biogenic silica and diatom analyses**.** At each interval notes were taken describing: the colour and composition of the sediment (Appendix 1). Before sediment was sampled, the exposed core surface was scraped away with a knife to ensure the sediment that was being sampled at that interval had not been carried up the core during extraction from the coring tube. Samples were taken from the core using a spatula. The spatula was used to make an outline

of 1 cm^2 on the surface of the log, the sample was then extracted from this area and used to fill a syringe to accurately determine that 1 cm^3 of sediment had been extracted.

Chronology

23 samples were analyzed from the top 30 cm of each gravity core for ^{210}Pb analyses. Approximately 100 mg of sediment was used for depths of 10 cm or less and 1g for sediment depths greater than 10 cm. Samples were taken from sections of the core where no facies changes occurred so that the samples were homogenous. The subsamples were dried and then crushed, using a mortar and pestle. The crushed samples were weighed in 50 mL centrifuge tubes. ^{210}Pb activity was determined using alpha spectroscopy at MyCore in Deepriver, Ontario (Cornett et al., 1984, & Rowan et al. 1995). Dates were determined using the Constant Rate of Supply model (Appleby et al., 2001). The CRS model implies that there is a constant rate of supply of fallout of ^{210}Pb. The CRS model is based on three main assumptions: 1) the rate of deposition of unsupported ^{210}Pb from the atmosphere is constant; 2) the ^{210}Pb in fresh waters originates in the atmosphere and is quickly removed from solution onto particulate matter and incorporated as unsupported ^{210}Pb , the main ^{210}Pb component in the surface sediments, and 3) the ^{210}Pb in sediments is not redistributed by post-depositional processes and decays exponentially with time in accordance to the radioactive decay law (Appleby et al., 2001).

Biogenic Silica and Diatom Analyses

Two 1 cm^3 samples, one for biogenic silica and one for diatom analyses, were taken at each interval using a sterile syringe. The sediment was placed into a plastic scintillation vial and stored at 4 °C.

Biogenic Silica

The 1 cm^3 of sample placed in the vial was removed from the fridge and the samples were uncapped, covered with Kim-Wipes and placed in a Labconco Triad Freeze Drier. Samples were left in the freeze drier for at least 24 hours or until all the water content had been removed from the sample (often took up to 48 hours). Once samples had been removed from the freeze drier they were individually crushed until they were ~100um using a mortar and pestle. After the samples were powdered, 20 mg of each sample was weighed out into 125 ml Nalgene bottle (the remainder of the crushed sample was stored in the original scintillation vial used to take the sample). The bottles were labelled with an identifying sample number to ensure the data being gathered and recorded was done so for the correct sample. Typically 24 to 28 bottles were measured and labelled for each run of biogenic silica.

Biogenic silica was measured using the wet alkaline approach outlined in DeMaster (1981) and Krausse et al. (1983). Total dissolved silica is composed of both biogenic silica and mineral silica. Biogenic silica can be made up of silica from chrysophytes, diatoms, phyoliths, protozoa, and sponge spicules. Biogenic silica dissolves completely within 2 hours. Because biogenic silica dissolves at a much

faster rate than that of mineral silica, the amount of silica from biological sources can be calculated as the Y-intercept when time is equal to 0.

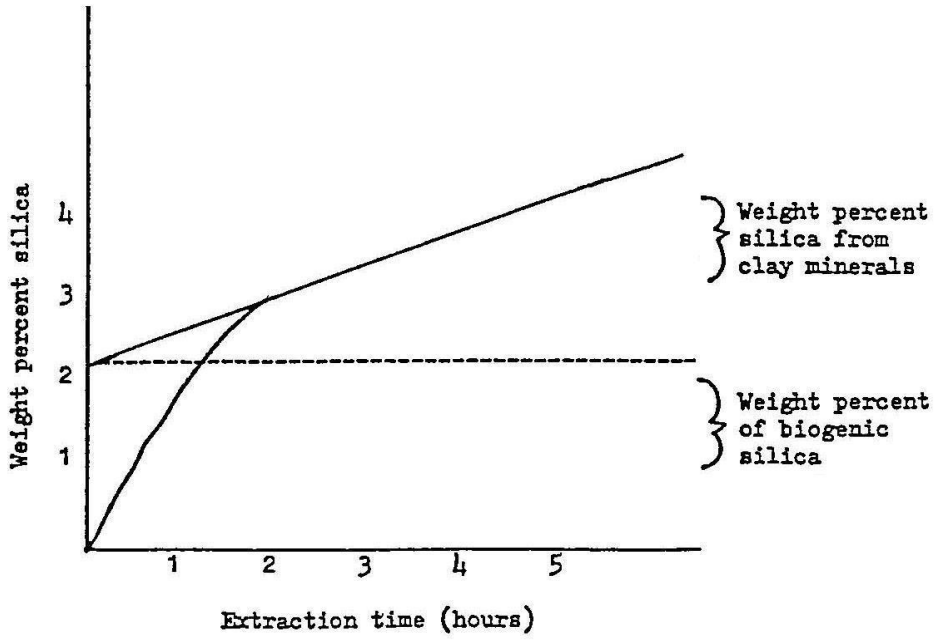

Figure 8 – Weighted percent silica verses extraction time. Total silica measured includes weighted percent of biogenic silica (silica from biogenic materials) plus the weight percent of silica from clay minerals. BSi dissolves completely within the first two hours of extraction and clay silica dissolves at a slower rate, the Y-int determines the amount of silica from biogenic sources (LARS BSi Lab Manual).

Powdered sediment samples were mixed with 40 mL of 1% sodium carbonate to dissolve the silica. Samples were heated in a shaker bath at 85 °C to ensure a complete reaction. At each time interval (2, 3 and 4 hours) 1 mL of each sample was taken, added to a test tube with 3.2 mL dilute HCl (3%) and 10 mL e-pure water to stop dissolution of silica. Once this is done for each of the 24 – 28 samples in the test run, the test tubes are capped and stored at 4 °C. This process is repeated at 3 hours and 4 hours and again both intervals are stored at 4 °C (stored at 4 °C to slow the reaction).

The following day, the samples were all removed from storage at 4 °C ahead to warm to room temperature, so that the reaction with the chemicals to be added would not be slowed. The spectrophotometer could run 12 samples at a time. Quartz cuvettes were filled with 0.64 mL of the sample, 0.84 mL of molybdate reagent, 0.64 mL of oxalic acid reagent, and 0.84 mL of ascorbic acid reagent. By following the following procedure, samples will turn blue, and the intensity of the blue will be related to the concentration of silica in the sample. This can be measured using a UVmini-1240 (UV-VIS Spectrophotometer) spectrophotometer.

A calibration is done by, making samples with a known amount of silica and measuring the intensity of the blue. The intensity of the blue of the given samples is measured and plotted against the known Si concentration. . Linear regression using least squares is used to determine an equation (i.e. slope and y-intercept) to determine SiO_2 of each of the standard. The regression is applied to the blue intensity for the unknown samples to determine their weighted percent of biogenic silica (DeMaster, 1981). X samples selected at random were re-run to determine the reproducibility of biogenic silica measurements at LARS.

Diatom Processing

Microscopic slides were prepared following standard procedures for diatom analyses (Battarbee et al., 2001) in order to determine what was contributing to the biogenic silica – diatoms, chrysophytes or both. Diatom processing requires many steps including: the addition of 10% hydrochloric acid (HCl) to remove carbonates

and the addition of a mixture of concentrated sulphuric and nitric acid to remove organics.

A 1 cm^3 sample was placed in a glass scintillation vial and mixed with 15ml 10% HCl. The samples were left for 24 hours, and then washed twice with E-pure water. Directly after, ~15ml of a 50:50 (by molar weight) mixture of concentrated sulphuric and nitric acid was mixed into the slurry. The vials were left for 24 hours and then placed in a hot water bath at ~80 degrees C for 2 hours. The samples were then left for 24 hours and then aspirated to ~1/3 volume. Approximately 15ml E-pure water was mixed with the sample and then the sample was left for 24 hours before being aspirated and washed again. This is repeated 10-14 times until the sample is neutralized (tested with litmus paper).

The processed samples were diluted to four different concentrations, and each dilution was pipetted onto a cleaned cover slip on a slide warmer. The four dilutions used here were: 1) Cover slip A is half slurry and half water; 2) Cover slip B is 1 part slurry to 3 parts water; 3) Cover slip C is 1 part slurry to 7 parts water; and 4) Cover slip D is 1 part slurry to 15 parts water. Slurries were left to dry for ~24 hours. Cover slips were then attached to a cleaned microscope slide using Naphrax®, a mounting medium. Approximately two drops of Naphrax® is placed on the slide and then the cover slip attached. Air bubbles are gently tapped out and then the slide is heated on a hot plate to evaporate the toluene in the mounting medium. Slides are left in the fume hood for 24 hours until dry.

Analysis of Diatom Slides

A qualitative approach was used to determine whether the biogenic silica was mainly from diatoms or Chrysophtes or something else. A slide from each sample from Little Trefoil Lake and the top and bottom of Dean Man's Hole were examined using a Leica E600 microscope equipped with Differential Interference Contrast (DIC) optics at 1000X magnification. Each slide was visually inspected and qualitatively evaluated as being composed of one of the following: 1) only diatoms; 2) only Chrysophytes; 3) mostly diatoms; 4) mostly Chrysophytes; 5) mixed (a 50:50 mix) of diatoms and Chrysophytes, and 6) no diatoms or Chrysophytes.

CHAPTER 4

RESULTS

Limnological Characteristics

Limnological data was recorded at Little Trefoil Lake on July 21st 2007 and August 6th 2008. Data at Dead Man's Hole was collected on July 21st 2007 and August 7th 2008.

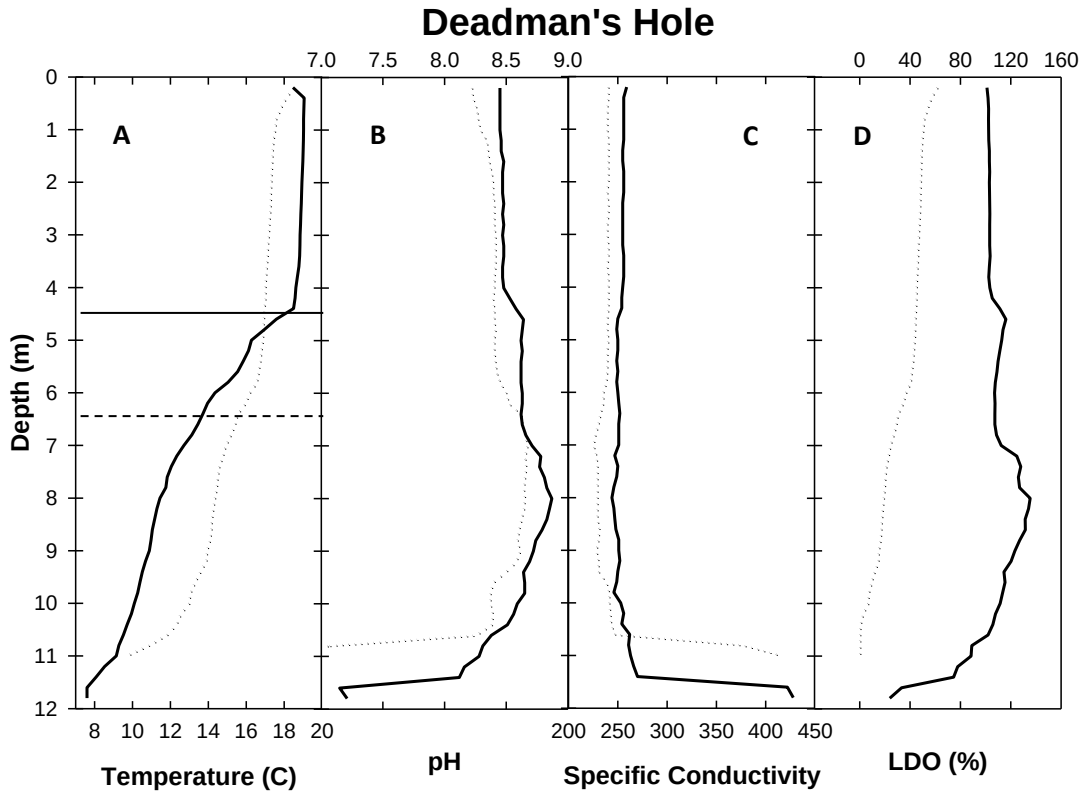

Figure 9: Temperature in C°, pH, specific conductivity (uS/cm^2) and level of dissolved oxygen (%) for Dead Man's Hole. The July 21st 2007 data is shown with the solid black line, the August 7th 2008 data shown with the dotted line. The thermocline is marked as a dashed line for 2008 and by a solid black line for 2007.

The temperature, pH and specific conductivity of Dead Man's Hole show similar profiles from one year to the other, although temperature profiles show that

in 2008 the thermocline (~6.5m) was deeper than in 2007 (~4.5m) (Figure 9a). Bottom temperatures are still quite warm suggesting mixing is occurring, which is somewhat surprising given the depth of the lake and the sheltered catchment. The 2008 DO is likely incorrect since values in the upper water are only ~75% when they should have been closer to 100%. The 2007 values are correct as the values in the upper water are at 100% DO. The high values of DO from the surface to ~ 10m indicate that the lake is low in productivity or well mixed by wind. The changes in pH and specific conductivity are similar between years and to be expected given the lower DO levels at the bottom of the lake.

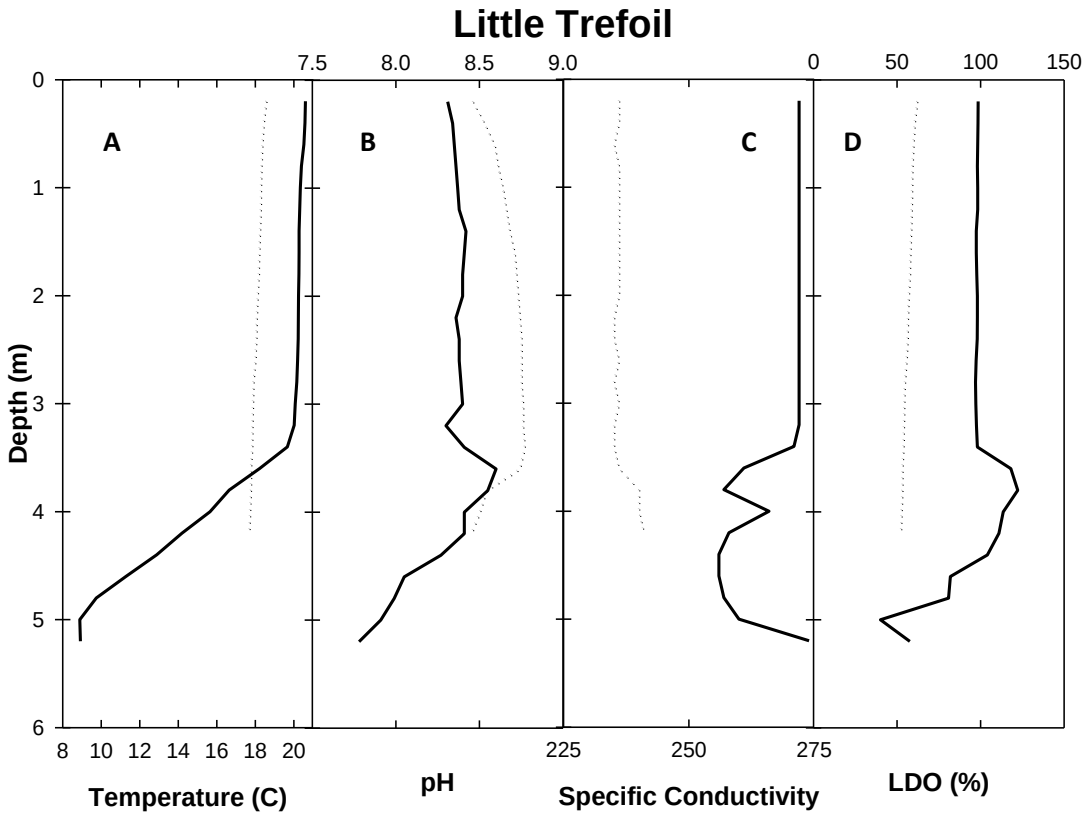

Figure 10: Temperature in C°, pH, Specific conductivity (uS/cm2) and level of dissolved oxygen (%) for Little Trefoil Lake. The 2007 data is shown with the solid black line, the 2008 data shown with the dotted line.

The temperature profiles for 2007 and 2008 for Little Trefoil are quite different (Figure 10). The 2008 profile shows that the lake was well-mixed and warm to the bottom (~18-19 ˚C), whereas the 2007 profile shows that the lake was stratified with a thermocline at about 3.5-4m. Upper waters were ~20˚C; bottom waters were 9˚C. The profiles for pH, specific conductivity and DO reflect the differences in thermal stratification between 2007 and 2008. Thermal stratification is the change in temperature at differing depths of a lake. A change in the waters density causes a change in the temperature of the water (U of Minnesota 2007).

Limnological data including major ions and nutrients were recorded at Little Trefoil Lake on August 6th 2008. Data at Dead Man's Hole was collected on July 21st 2007 and August 7th 2008 (Table 1).

Lake Name	Major Ions (mg/L)							
	Ca	K	Mg	Na	SO4	Cl	SiO2	Ortho P
Dead Man's Hole	33.338	0.501	12.004	2.402	30.372	2.113	4.09	BD
Little Trefoil (#3)	31.553	0.99	14.756	2.916	23.199	1.957	4.4	BD
	Nutrients (Phosphorus and Nitrogen) and Carbon (Organic and Inorganic)							
		NO2+NO3	NH4	T.O.C	T.I.C	T.P.	T.N.	TN/TP
Dead Man's Hole		14 µg/L	8 µg/L	2.323 mg/L	23.907 mg/L	2.6 µg/L	203 µg/L	172.81
Little Trefoil (#3)		13 µg/L	10 µg/L	7.974 mg/L	23.534 mg/L	6.8 µg/L	695 µg/L	226.15

Table 1: Major Ions and Nutrients in Dead Man's Hole and Little Trefoil Lake. Both lakes are phosphorous deficient (TN/TP). Values below 20 indicate are nitrogen deficient, values above 50 are phosphorous deficient (Guildfird and Hecky, 2000).

The two lakes show roughly the same levels in major ions and nutrients. Both lakes are oligotrophic, as suggested by the TP values, and P-limited. Lakes situated in limestone are often P- limited because P can be co-precipitated with $CaCO_3$ (Wetzel, 2001). As well, the lakes are characterized by relatively low values of silicate. The main difference between the two lakes is TOC concentrations, which is ~3X greater in Little Trefoil Lake compared to Dead Man's Hole. .

Accuracy and Reproducibility of BSi Data

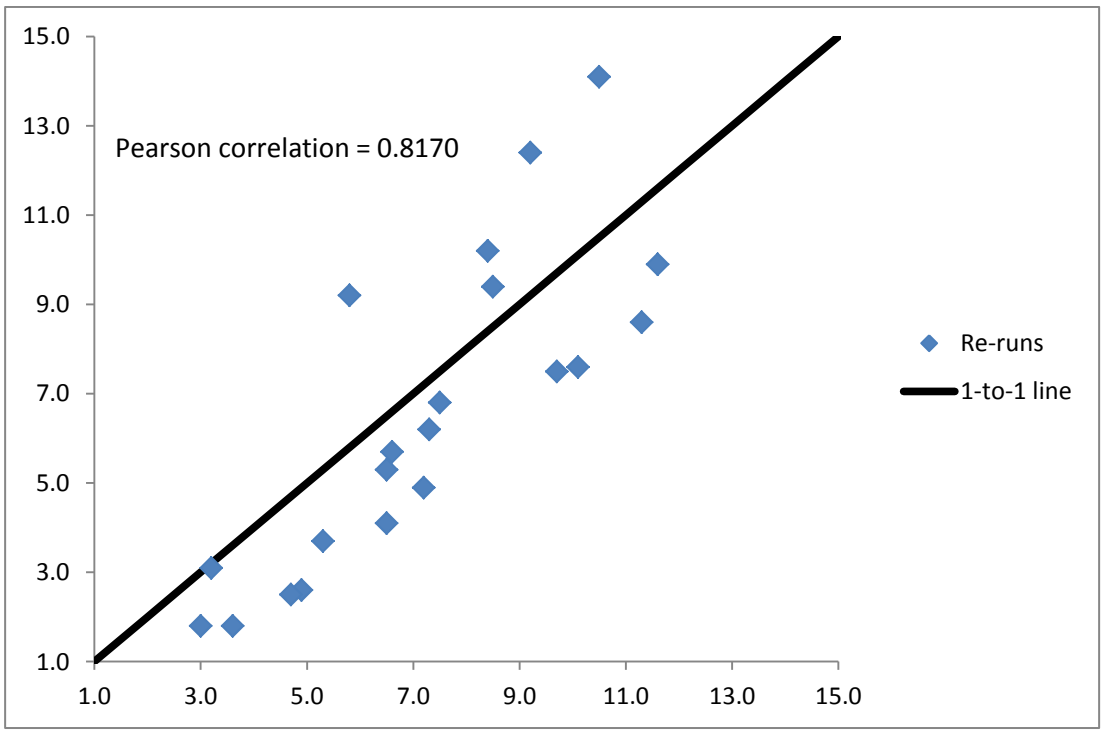

Figure 11: Biogenic Silica re-runs for little trefoil lake

If BSi measurements were the same for different runs then the sample points in Figure 11 would fall on the one-to-one line. The results show that in most cases the points do fall close to this line, although greater values of BSi have larger

differences in values. The Pearson Correlation Coefficient (or r value) is 0.817 which indicates that the data points have a high positive correlation.

Sediment Description

The cores from Little Trefoil Lake were mainly organic, sometimes laminated, dark brown sediments with terrestrial macrofossils (fossils were extracted during the sampling process) (Figure 14). Core 1 from Little Trefoil had three tephra layers, which for this thesis are assumed to be Mazama 7588 years BP (Pyne-O'Donnell et al., 2012), Mount St. Helens Y 3664 years BP (Pyne-O'Donnell et al., 2012), and Bridge River years 2370 BP (Pyne-O'Donnell et al., 2012). Pending funding these tephra layers will be accurately identified and dated. Core 2 from Little Trefoil only contained one tephra layer which most likely matched up with the Bridge River 2370 yrs BP from core 1.

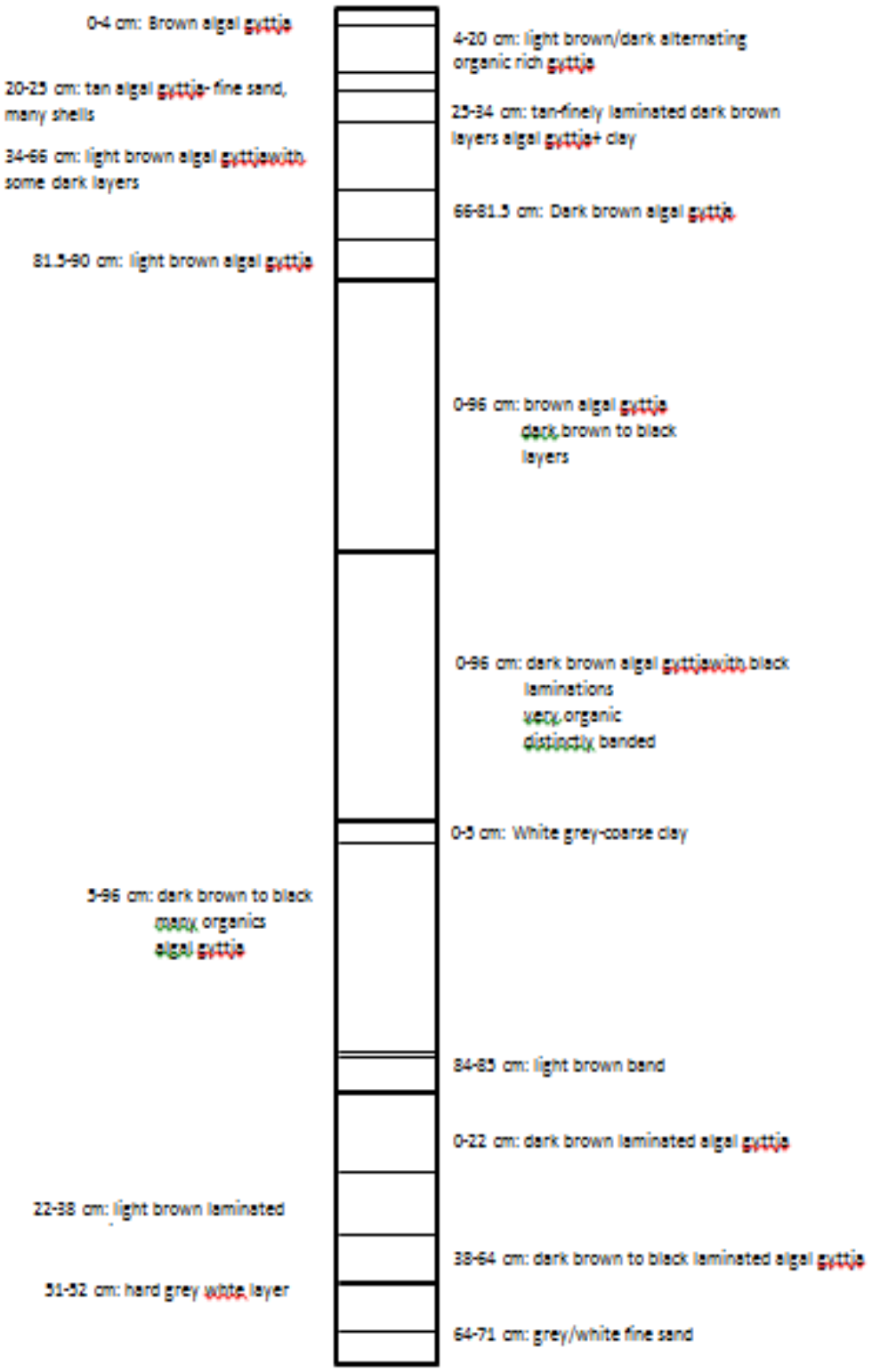

Figure 12: Core Description for Little Trefoil Lake 07-JP-02 core 1.

The cores from Dead Man's Hole were much lighter in colour representing less organics and siltier, clay sediments (Figure 15). Distinct laminations were observed. This core was characterized by abundant macrofossils and at the bottom of the core large pieces of wood were observed.

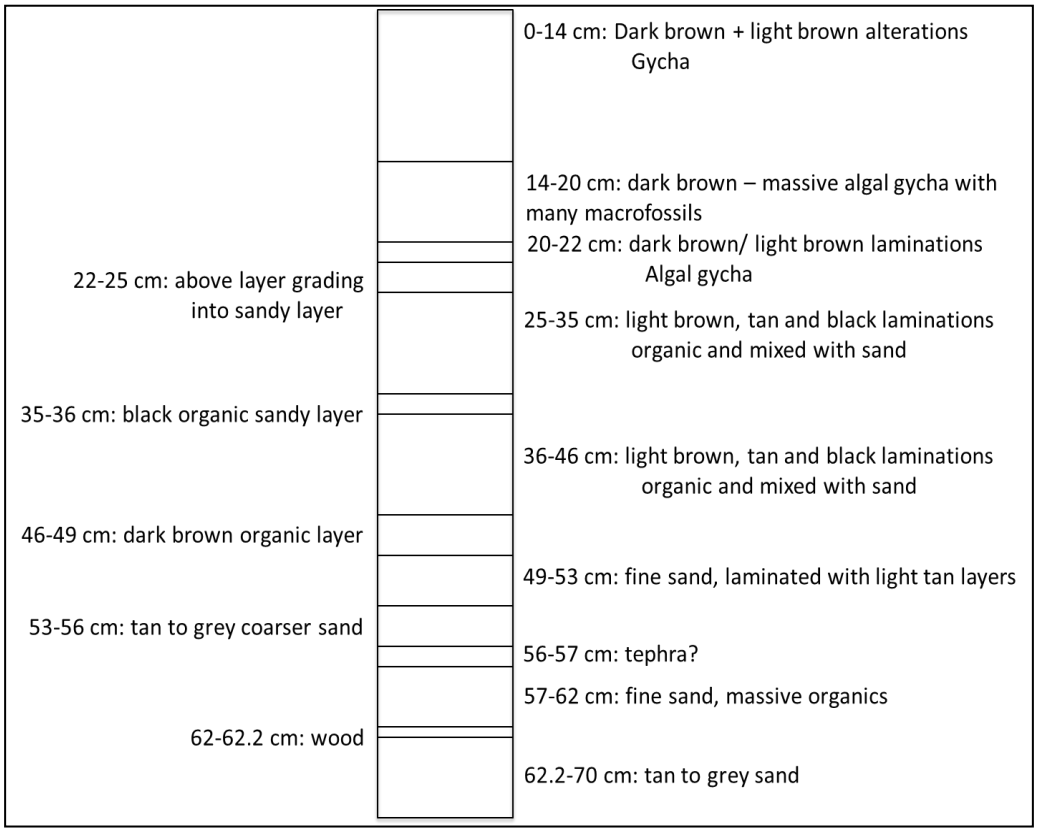

Figure 13: Core Description for Dead Man's Hole 07-JP-01 Long core.

Chronological Control

Dates for the first 30 cm of the Little Trefoil Lake core were obtained using ^{210}Pb. Dead Man's Hole was dated, but a chronology was not developed because biogenic silica was consistently low (see below). The ^{210}Pb ages were plotted against the depth they came from and were fitted with a linear line of best fit (Figure 13).

The best fit line was used to determine the dates for depths to 30 cm. Although three tephra layers were observed and sampled in the Little Trefoil core, they have not been officially identified, but we believe they represent the Bridge River Tephra; the Mount St. Helens tephra, and the Mazama tephras (Figure 12). Therefore, for depths below 30 cm, a line was fit between the last ^{210}Pb dates and the Bridge River tephra, and then the Bridge River and the Mount St. Helen's date and finally the Mt. St. Helens and Mazama. Funds are now available to have the tephras identified and for ^{14}C dates. At present, however, my method of interpolating dates is limited by the unknown accuracy of the tephra dates and the assumption that sedimentation rate is the same between tephras – which is unlikely. Unfortunately, at this point this is the best chronological control we are able to produce.

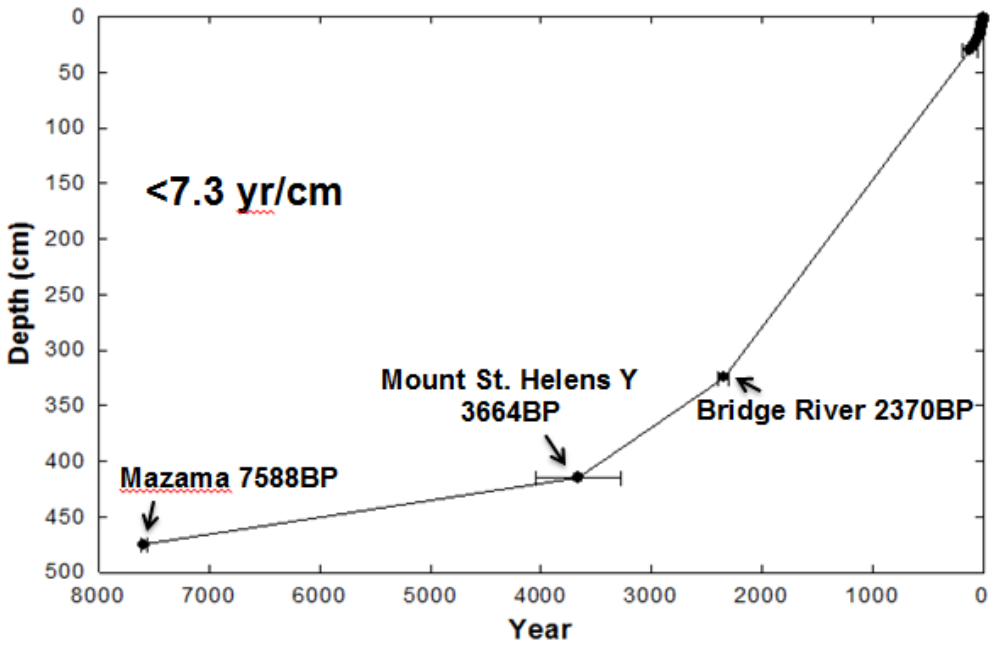

Figure 14: ^{210}Pb dates in relation to tephra dates, ^{210}Pb is seen at the top of the plot between 0-50 cm, tephra dates are labled with their coresponding dates.

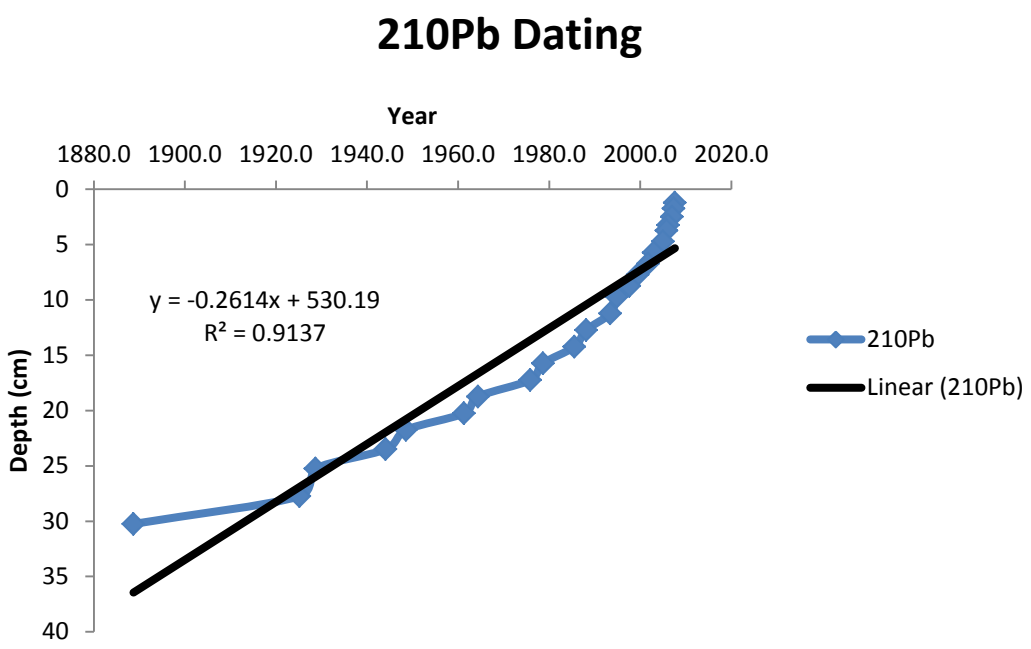

Figure 15: ^{210}Pb dates plotted with a linear line of best fit.

Biogenic Silica

Biogenic silica (BSi) was measured at 10 cm intervals (later converted to absolute depth below the sediment water interface) in core 1 and 2 of Little Trefoil Lake and was measured at 5cm intervals (also converted to absolute depth below the sediment water interface) in the core from Dead Man's Hole. The weighted percent BSi was plotted against sample depths (Figure 16 and 17). The levels of biogenic silica were so minimal for Dead Man's Hole that not further inquiry was done on the core.

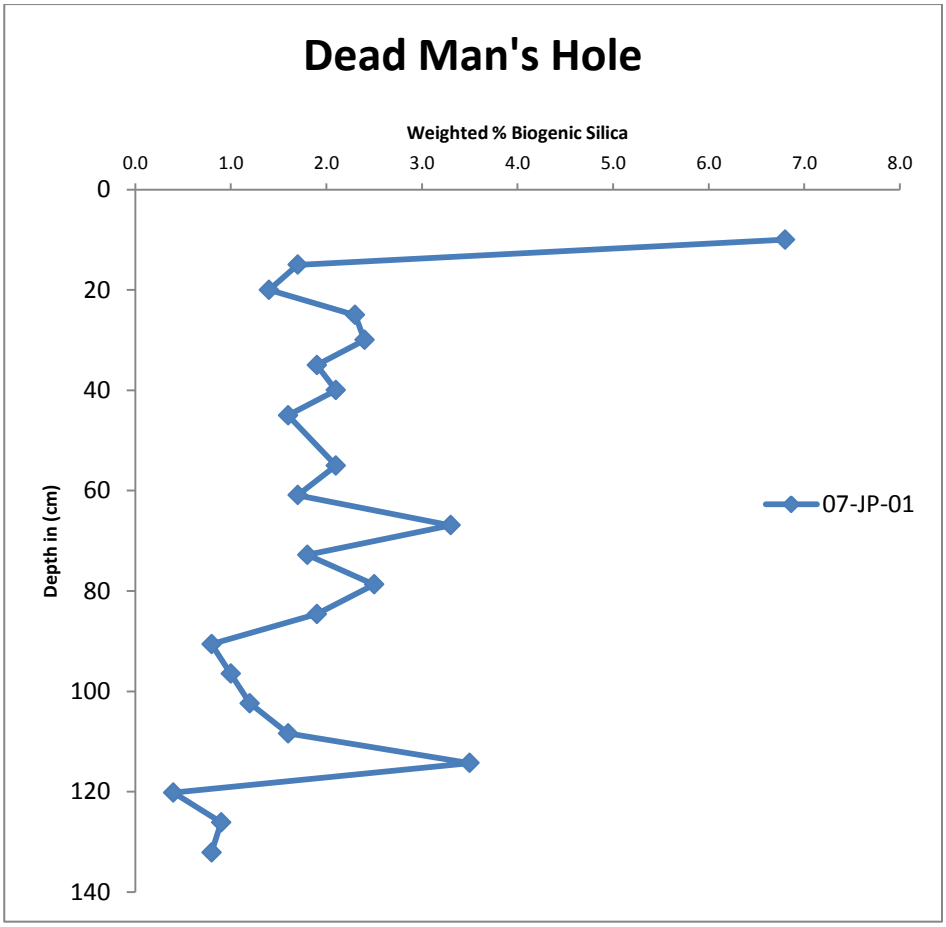

Figure 16: Dead Man's Hole long core, weighted % biogenic silica plotted against depth.

The depths were assigned a date using the equations determined above. The two plots show that the weighted percent varies throughout both cores, but there are definitive peaks that occur. These peaks, along with the tephras, can be used to correlate between the cores in order to use the dates determined for core 1 to determine ages for core 2 when future analyses are made (Figure 17). For the remainder of this thesis we will only discuss the results from core 1.

BSi and relationships to age for core 1 are shown in Figure 17. Peaks in BSi in core 1 occur at ~1.25 meters (~ 550 yrs BP) in depth, ~3 meters in depth (~ 2000 yrs BP).

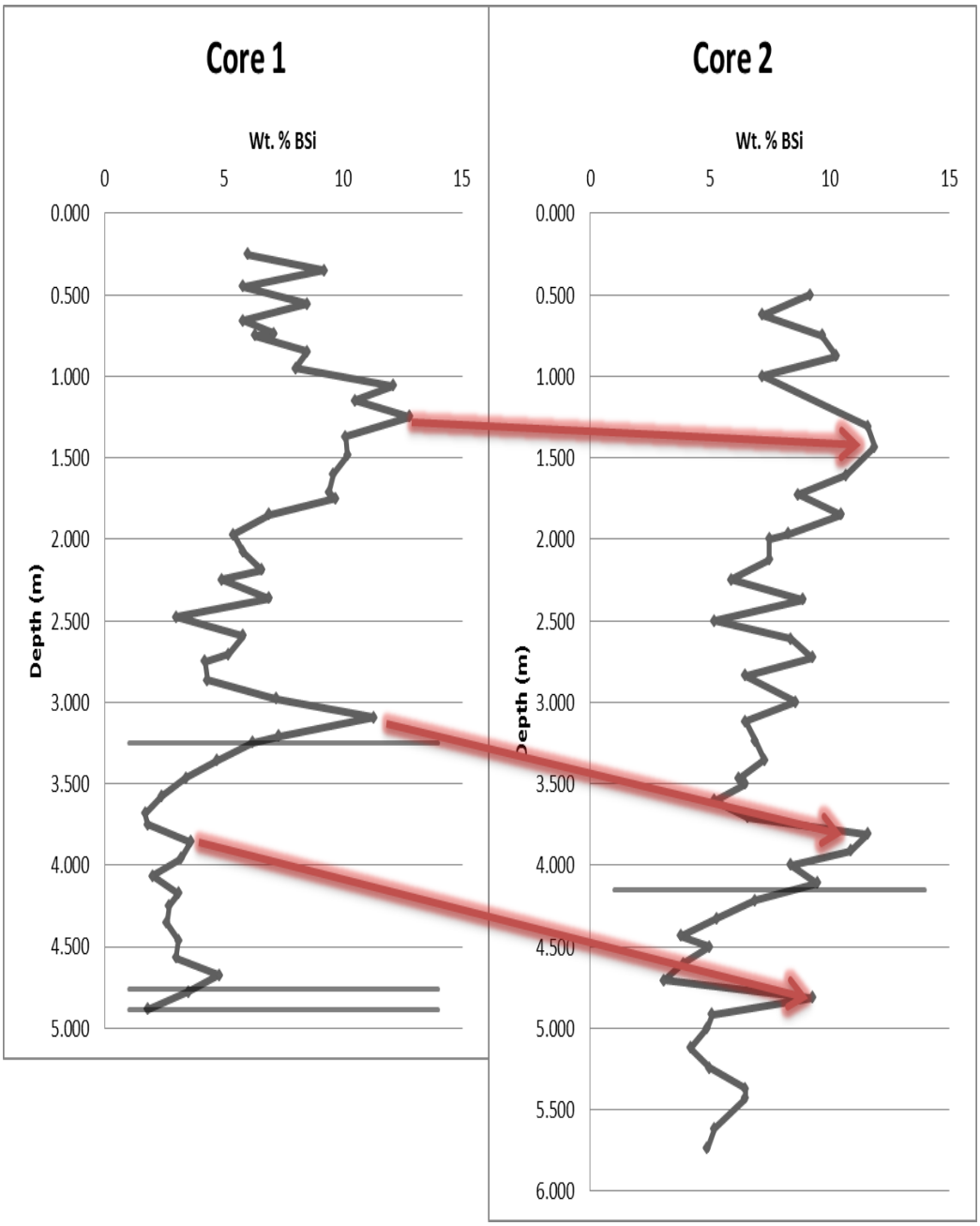

Figure 17: The peaks in Biogenic Silica in 07-JP-02 core 1 at depth being correlated to the peaks in Biogenic Silica in 07-JP-02 core 2 at sediment depth. The correlation is based on tephra depths and weighted percent of Biogenic Silica of those peaks.

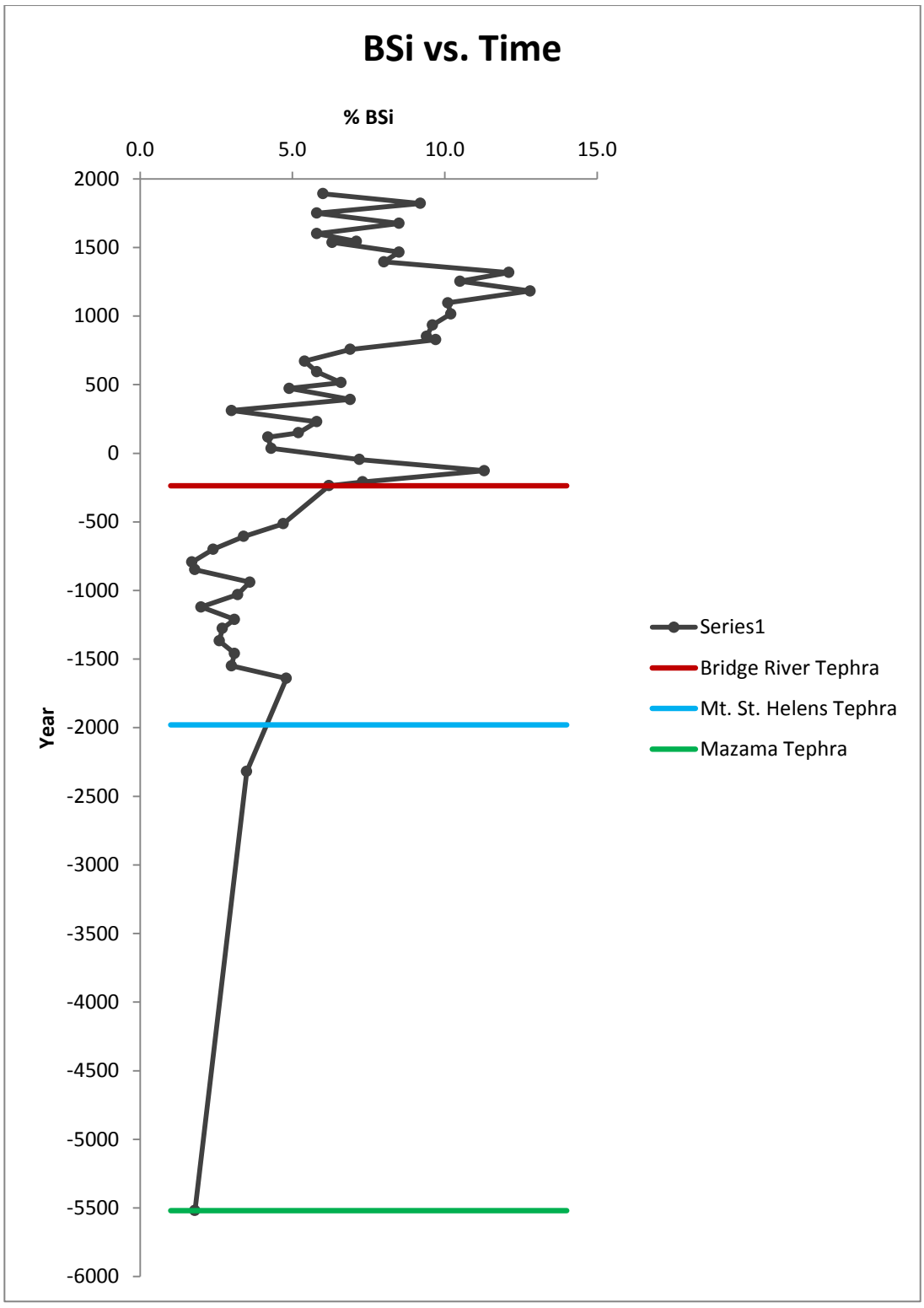

Figure 18: Weighted percent of Biogenic Silica in core 1 in relation to time of deposition. The time is in reference to the present date although the sedimentation rate was calculated using BP (year 1950).

Origin of Biogenic Silica

Qualitative evaluation of diatom slides indicates that in Little Trefoil Lake there are well-preserved diatoms and chrysophytes, but also small broken bits of diatoms, whereas in Dead Man's Hole there were almost no diatoms or chrysophytes observed. This is consistent with the low BSi values in the Dead Man's Hole samples. In Little Trefoil Lake two general trends are noted; the abundance of diatoms seems to be increasing towards the present, and the peaks seem to contain more diatoms than the troughs.

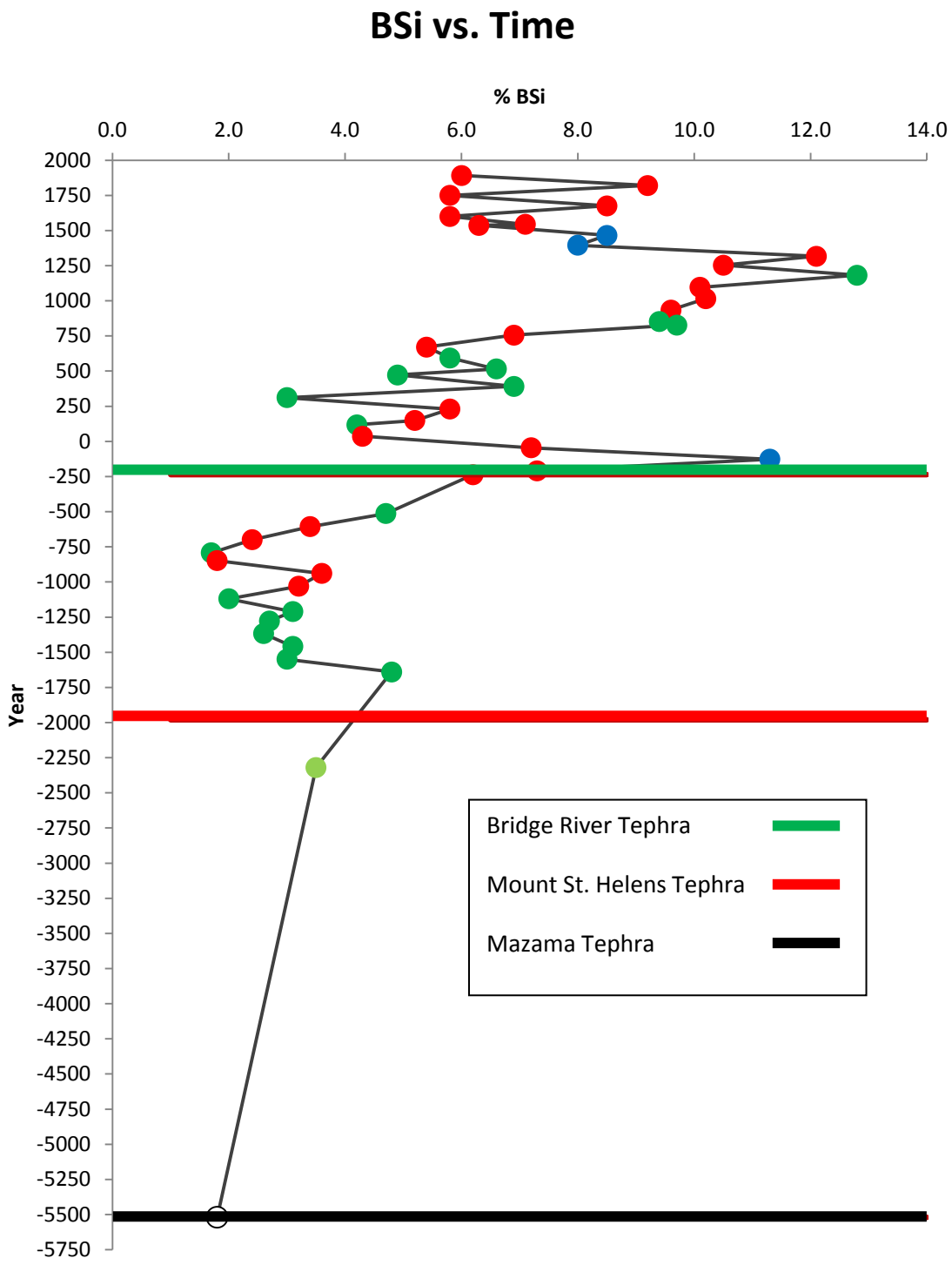

Figure 19: This figure shows the origin of the biogenic silica. Red dots represent mixed samples, green dots represent samples with mostly chrysophytes, blue dots represent samples with mostly diatoms, light green dots represent samples with only chrysophytes, and white dots represent samples with no presence of either diatoms or chrysophtyes. Note: no samples had only diatoms.

CHAPTER 5

DISCUSSION

Objective 1: To determine whether the biogenic silica measurement procedures developed in the Lake and Reservoir Systems (LARS) Research Facility provide reproducible measures.

Values for reruns in this study were plotted with both a line of best fit (going through the point 0, 0) and a 1-to-1 line to show the variation between the values gained from the two separate runs. The data had an r value of 0.817 with respect to the Pearson Correlation Coefficient, which implies a high positive correlation between the data points and a 1-to-1 ratio. The values of biogenic silica for the samples that were rerun is important for determining that the Biogenic Silica extraction method is feasible and accurate for determining the level of diatom productivity in the samples.

Objective 2: Testing the feasibility of using BSi in cores from Jasper National Park

Low biogenic silica concentrations indicate that either diatom and chrysophyte production in the lakes is low or that diatom and chrysophyte preservation is poor. Low preservation may be as a result of high temperature, high pH values, high salinity values, or high alkalinity (Hobbs et al., 2010). Diatoms from Banff have been found to completely dissolve within 50 years of deposition (Hobbs et al., 2010). It has been suggested that poor preservation in the Rocky Mountain region of Canada may be as a result of the nature of the lakes. Lakes that are warm, alkaline and saline all have a low preservation potential for diatoms (Hobbs et al.,

2010). However, neither Dead Man's Hole nor Little Trefoil Lake are characterized by pH values >10 (when silica dissolves) or by particularly warm temperatures. Unfortunately, we do not know the alkalinity of the lakes, but any diatoms that are present are well preserved showing no signs of dissolution. This suggests that preservation is not a problem in either of these lakes. It is unclear at this time why diatom and chrysophyte production in Dead Man's Hole is so low, but it could be related to low TP and SiO_2 values noted at the site. However, these variables are also low in Little Trefoil Lake where diatom and chrysophyte production is greater. These results indicate that diatoms and chrysophytes are well preserved and could be used to infer past environmental conditions, particularly changes in lake productivity, in this region.

Objective 3: Determine changes in lake production overtime and speculate about what could be driving these changes.

The greater biogenic silica concentrations in Little Trefoil Lake in comparison to Dead Man's Hole shows that Little Trefoil Lake has greater diatom production than Dead Man's Hole. At this point in time it is unclear why this is the case.

Peaks in biogenic silica then indicate increased production in diatoms and chrysophytes and may be due to warmer temperatures. Because samples in the peaks generally contain more diatoms than samples from the troughs, this suggests the peaks are characterized by more eutrophic conditions and warmer temperatures (Smol et al., 2005).

The first peak seen in Core 1 (Figure 19) appears to be located around the time of the Medieval Warming Period which occurred between the years of 950 to 1250 A.D. (Mann et al., 2009). Warmer air temperatures would lead to warmer water temperatures (Livingstone et al., 1999) and more eutrophic conditions (Livingstone et al., 1999).

The second peak seen in Core 1 (Figure 19) is located before what is assumed to be the Bridge River Tephra. However, there is no way of connecting the volcanic event to a change in climate. The correlation between the two events may be unrelated.

In general, the biogenic silica tests used give an accurate and reproducible representation of the diatom productivity in Jasper National Park, Alberta. The reasons for peaks and drops is biogenic silica throughout the Holocene, however requires better dating control.

CHAPTER 6

CONCLUSION

These experiments were done to determine whether or not biogenic silica is a feasible determinant of diatom productivity, determine whether or not the experiment to test for biogenic silica is reproducible, and lastly to determine what could be causing peaks in biogenic silica throughout the sediment record in Jasper National Park.

The reproducibility of the experiments was reasonable compared to other laboratory results that have run the same wet-alkaline approach to determine the weighted percent of biogenic silica within a sample (Conley et al., 1998).

Biogenic silica proved to be a good determinant of diatom productivity in both of the sampled lakes although both of the lakes had low diatom and chrysophyte production with Dead Man's Hole having little to no siliceous algal production.

The peaks in biogenic silica in Jasper National Park are most likely the result of climatic influences; little evidence indicates changes related to recent human activity (Tande, 1979), although this may be related to the low chronologic resolution.

Further research should go into determining the relative abundance of diatoms and chrysophytes to better understand variations in the origin of the

biogenic silica. By looking at the diatom community composition or other proxies in the samples it may help to better understand the drivers of changes in siliceous algae productivity.

REFERENCES CITED

Appleby, P.G. 2001. Chronostratigraphic Techniques in recent sediments**.** In J.P. Smol, J.B. Birks & W.M. Last (Eds.), *Tracking Environmental Change Using Lake Sediments Volume1: Basin Analysis, Coring and Chronological Techniques*, Kluwer Academic Publishers pp**.** 171-203

Battarbee, R.W., D.F. Charles, S.S. Dixit, & I. Renberg. (1999) Diatoms as indicators of surface water acidity. In: Stoermer, E.F. & Smol, J.P. (Eds.) *The Diatoms: Applications for the Environmental and Earth Sciences*, Cambridge University Press, Cambridge, 85–127.

Battarbee, R., L. Carvalho, S. Juggins. 2001. Diatoms. In J.P. Smol, J.B. Birks & W.M. Last (Eds.), *Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal and Siliceous Indicators*, Kluwer Academic Publishers, pp. 155-202

Bormann, F.H. and G.E. Likens. 1974. Linkages between Terrestrial and Aquatic Ecosystems. *Bioscience*, Vol. 24, No. 8, pp. 447-456

Bradbury J.P., Colman S.M. and Dean W.E. 2004b. Limnological and climatic environments at Upper Klamath Lake, Oregon during the past 45,000 years. *J. Paleolimnol*. 31: 167–188.

Conley, D.J. 1988. Biogenic silica as an estimate of siliceous microfossil abundance in Great Lakes sediments. *Biogeochemistry* 6: 161-179

Conley, D.J., and C.L. Schelske. 1993. Potential role of sponge spicules in influencing the silicon biogeochemistry of Florida lakes. *Can. J. Fish. Aquat*. Sci. 50: 296-302.

Conley, D.J. 1998. An interlaboratory comparison for the measurement of biogenic silica in sediments. *Marine Chemistry* 63: 39-48

Conley, D.J. and C.L. Schelske. 2001. Biogenic silica. In J.P. Smol, J.B. Birks & W.M. Last (Eds.), *Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal and Siliceous Indicators*, Kluwer Academic Publishers, pp. 281-293.

Cornett, R.J., L. Chant, D. Link. 1984. Sedimentation of Pb-210 in Laurentian Shield lakes. *Res. J. Canada*: Vol. 19: No. 2 pp. 97-109

Demaster, D.J. 1979. The marine budgets of silica and ^{32}Si. Ph.D. thesis, Yale University

Demaster, D. J. 1981. The supply and accumulation of silica in the marine environment. *Geochim. Cosmochim. Acta* 45: 1715-1732.

Environment Canada. 2009, July 7. Government of Canada. *Canadian Climate Normals 1971-2000.*

Glew, J.R., J.P.Smol, W.M. Last. 2001. Sediment core collection and extrusion. In J.P. Smol, J.B. Birks & W.M. Last (Eds.), *Tracking Environmental Change Using Lake Sediments Volume1: Basin Analysis, Coring and Chronological Techniques*, Kluwer Academic Publishers pp. 73-105

Hobbs, W.O., S.V. Lalonde, R.D. Vinebrooke, K.O. Konhauser, R.P. Weidman, M.D. Graham, A.P. Wolfe. 2010. Algal-silica cycling and pigment diagenesis in recent alpine lake sediments: mechanisms and paleoecological implications. *J.Paleolimnol* 44: 613-628

Krause, G.L., C.L. Shelske, C.O. Davis. 1983. Comparison of three wet-alkaline methods of digestion of biogenic silica in water. *Freshwater Biology* 13: 73-81

Livingstone, D.M., A.F. Lotter, I.R. Walker. 1999. The decrease in summer surface water temperature with altitude in Swiss alpine lakes: A comparison with air temperature lapse rates. *Arctic, Antacrtic, and Alpine Research,* Vol 31, No.4 pp. 341-352

Mann, M. E., Z. Zhang, S. Rutherford, R.S. Bradley, M.K. Hughes, D. Shindell, C. Ammann, G. Faluvegi et al. (2009). Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly. *Science* 326 (5957): 1256–60

Moser, K.A. 2004. Paleolimnology and the frontiers of biogeography. *Physical Geography.* 25, 453-480

Mountjoy, E.W. 1964. Rocky Mountain front range between Rocky River and Medicine Lake, Jasper National Park, Alberta. In Edmonton Geological Society 6th annual fieldtrip guidebook, pp. 1-13

Parks Canada. (2009, April 15). Parks Canada. *Jasper National Park of Canada is buring for conservation.* Retrieved on March 5, 2013 from http://www.pc.gc.ca/docs/v-g/ie-ei/at-ag/sec8/page2.aspx

Patrick, R. 1977. Ecology of freshwater diatoms and diatom communities. In: The Biology of Diatoms, D. Werner (Ed.). Blackwell Scientific Publications, Botanical Monographs Vol. 13, pp. 284-332

Prince, R.A. and E.W. Mountjoy. 1970. Geological Structure of the Canadian Rocky Mountains between the Bow and Athabasca Rivers – a progress report. *Geological Association of Canada Special Paper 6*

Pyne-O'Donnell, S.D.F., Hughes, P.D.M., Froese, D.G., Jensen, B.J.L.; Kuehn, S.C., Mallon, G, Amesbury, M.J., Charman, D.J., Daley, T.J., Loader, N.J., Mauquoy, D., Street-Perrott, F.Al., Woodman-Ralph, J. 2012. High-precision ultra-distal Holocene tephrochronology in North America. *Quaternary Science Reviews*, 2012, 52, 6-11, Elsevier

Rowan, D.J., R.J. Cornett, K.J. King and B.A. Risto, 1994. *J. Paleolimnology*. 13:107-11.

Smol, J.P. 2002. *Pollution of lakes and rivers: A paleoenvironmental perspective.* Kingston, Canada: Queens University.

Smol, J. P., et al. 2005. Climate-driven regime shifts in the biological communities of arctic lakes, *Proc. Natl. Acad. Sci. U. S. A*., 102, 4397 – 4402.

Smol, J.P. 2008. *Pollution of lakes and rivers: A paleoenvironmental perspective*, 2nd Edition. Oxford, UK: Blackwell Scientific Publishing Inc. 383 pp.

Tande, G.F. 1979. Fire history and vegetation pattern of coniferous forests in Jasper National Park, Alberta. *Can. J. Bot.* 57: 1912-1931

University of Minnesota. 2007. *Density Stratification: part of an educational website*. Retrieved on April 25, 2013 from http://www.waterontheweb.org/under/lakeecology/05_stratification.html

Wetzel, R.G. 2001. *Limnology Lake and River Ecosystems, 3rd Edition.* USA: Academic Press. 1006 pp.

Zeeb, B.A. and J.P. Smol. 2001. Chrysophyte Scales and Cysts. In J.P. Smol, J.B. Birks & W.M. Last (Eds.), *Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal and Siliceous Indicators*, Kluwer Academic Publishers, pp. 203-223.

APPENDIX

Appendix 1 – Core Sampling Laboratory Notes

1st longcore

- 07-JP-02-1A (5-6m) (0-50cm)

0-20 cm

- Dark brown

20 – 32 cm

- Tan colour
- At 24.5 cm "sandy" ring
- 26-32 cm alternating rings of dark and light

32 – 50 cm

- Dark
- Gets darker towards 50 cm
  Picture

Samples

0-1cm

- Dark
- Spongy
- End of the core was loosely packed, sample was taken from loosely packed sediment located between the 0-1 cm mark

Macrofossils @ 3-4 cm, @6-7 cm

10-11cm

- Dark spongy
- Exposed layer was wiped away with a knife horizontally across core to not spread sediment

20-21cm

- On divide between dark and light sediment
- Mostly light sediment
- Exposed layer wiped with knife
- No macrofossils

30-31cm

- Light sediment
- Visible dark rings
- Exposed layer wiped with knife
- Small macrofossil shell found

40-41cm

- Dark sediment
- No visible rings
- Exposed layer wiped with knife
- No macrofossils

49-50cm (overlap of next core)

- Loosely packed
  Sample taken from loosely packed sediment
- Dark in colour
- No macrofossils

1st Longcore

- 07-JP-02-1A (5-6m) (50-90cm)
- Mostly dark in composition
- Faint rings of varying colour can be seen
- Very dark from 75-80cm
  Picture

Samples

50-51 cm

- Loosely packed
  Sample taken from this
- Dark material
- No macrofossils

60-61 cm

- Knife swipe to remove exposed layer
- Dark material
- No macrofossils

70-71 cm

- Knife swipe to clean
- Dark material
- Macrofossil found

80-81 cm

- Darker than the rest of this core
- Knife swipe done
- No macrofossils

90-91 cm

- Loose material
- No knife swipe possible
- No macrofossils

Notes:

- Put into dry freeze May 28th

2nd Longcore

- 07-JP-02-1B (6-7m) 0-50cm)
- Medium to dark
- 0-43cm
- Visible banding
  Picture

Samples

0-1 cm

- Loose material
  No knife swipe possible
- No macrofossils

10-11 cm

- Cleaned with knife swipe
- No macrofossils
- Medium colour

20-21 cm

- Cleaned with knife swipe
- Medium to lighter colour
  With respect to this core

Macrofossils @ 17.5-20 cm

30-31 cm

- Medium colour
- Cleaned with knife swipe
- No macrofossils

40-41 cm

- Cleaned with knife
  Semi-loose material
- Darker in colour
- No macrofossils

2nd Longcore

- 07-JP-02-1B (6-7m) (50-90cm)
- Rings at 63-68cm
  Rings are slightly darker than the rest of the core
  Picture

Samples

50-51 cm (beginning of core)

- Lighter part of material
- Cleaned with knife

60-61 cm

- Cleaned with knife
- No macrofossils
- Lighter sediment
  Just before banding

70-71 cm

- Lighter brown sediment
- Just after darker ring
- Cleaned with knife
- No macrofossils

80-81 cm

- Medium brown sed.
- Cleaned with knife
- Macrofosssils present
  Sample taken and labelled

90-91 cm

- Darker brown
- Cleaned with knife
- No macrofossils

3rd Longcore

- 07-JP-02-1C (7-8m) (0-50cm)
- Medium brown to dark brown
  As you move from 0-50cm
- Only 46cm long
- White substance present
  Picture

Samples

0-1 cm

- Loose material
  No knife swipe
- Very organic
- No macrofossils

10-11 cm

- Cleaned with knife
- Darker brown sed.
- No macrofossils

20-21 cm

- Cleaned with knife
- Right next to break in core
- Same dark brown as before
- No macrofossils

30-31 cm

- Cleaned with knife
- Dark brown
- No macrofossils

40-41 cm

- Loose material
  Attempted to scrape with knife – fell apart
- Dark in colour
- No macrofossils

<u>3rd Longcore</u>

- 07-JP-02-1C (7-8m) (50-96cm)
- Dark brown
- Definite banding/rings
- Only 42cm long
- White substance at 40cm (90cm)
  Picture

Samples

50-51 cm

- Cleaned with knife
- End of core
- Dark brown
- No macrofossils

60-61 cm

- Cleaned with knife
- Organic
- Dark brown
- No macrofossils

70-71 cm

- Cleaned with knife
- Dark brown

Macrofossil @ 68.5-70 cm

80-81 cm

- No macrofossils
- Cleaned with knife
- Dark brown

90-91 cm (end of core)

- Loose material
  Attempted knife swipe
- White substance
  Looks like gravel/sand/rock
- Dark brown

Notes:

- Replaced tin foil and plastic wrap

<u>4th Longcore</u>

- 07-JP-02-1D (8-9m) (0-50cm)
- Dark brown
- 46cm long
- White/tan coloured substance (first 9 cm)
  Tephra??
- Very faint banding
  Picture

Samples

0-1 cm

- Loose material
  Scraped away with knife
- Light tan colour
- Sample included “Tephra”
- No macrofossils present

10-11 cm

- Lighter brown than further down core
- At the end of "tephra" area
- Cleaned with knife
- No macrofossils

20-21 cm

- Transition between darker ring and medium brown ring at 20 cm
- Cleaned with knife
- No macrofossils

30-31 cm

- Darker brown sed
- Cleaned with knife

Macrofossil @ 30.5 cm (stick)

40-41 cm

- Dark brown
- Cleaned with knife
- No macrofossils present

<u>4th Longcore</u>

- 07-JP-02-1D (8-9m) (50-96cm)
- Very dark (almost black-brown)
  Very Organic
- White substance @ beginning (i.e. 50 cm mark)
- Small stone 18-19cm
  Picture

Samples

50-51 cm

- Dark brown
- Attempted to clean with knife swipe
  Loose material fell apart
- No macrofossils

60-61 cm

- Dark brown
- Cleaned with knife swipe
- No macrofossils present

70-71 cm

- Medium brown
- Sample taken just after stone in core
- Cleaned with knife
- No macrofossils

80-81 cm

- Dark brown
- Cleaned with knife
- No macrofossils

90-91 cm

- Cleaned with knife
- Dark brown
- No macrofossils

Notes:

- Second core was only 43 cm long
  Supposed to be 46 cm
- Changed plastic wrap

<u>5th Longcore</u>

- 07-JP-02-1E (9-10m) (0-71cm)
- Only one core
  Not split into parts
- Core was taken on an angle
- Only measures 68 cm
- 0-22cm dark brown layer
- 22-41cm light brown area
  Small white grains present
- 41-68cm dark brown layer
  Layer has:
  44-54cm orange and white harder "rock" or gravel like substance
  61-65cm grey "tephra" or sand
  Picture

Samples

0-1 cm

- Loose material
- Could not clean with knife
- Dark brown material
  Organic?
- No macrofossils

10-11 cm

- Loose material
- Outer layer flaked away with knife
- No macrofossils
- Dark brown material

20-21 cm

- Light brown material
- Cleaned with knife
- No macrofossils
- More mud-like (packs well , doesn't flake)

30-31 cm

- Cleaned with knife
- Light brown material
  Has small white shells/shell fragments
- No macrofossils other than shell fragments
  Too small to sample

40-41 cm

- Medium brown material
  Just before dark material
- Cleaned with knife
- No macrofossils

50-51 cm

- Orange and sand layer runs through dark brown material
- Cleaned with knife
- No macrofossils
- Orange sandy substance is in the sample taken

60-61 cm

- Cleaned with knife swipe
- Dark organic material
- No macrofossils

<u>6th Longcore</u>

- 07-JP-02-2A (5.25-6m) (0-50cm)
- Lighter brown
- Slight laminations
- Only 43 cm
- 40-43cm is grainy
  Picture

Samples

0-1 cm
- Cleaned with knife
- Loose material
- No macrofossils
- Darker brown compared to this core

10-11 cm
- Lighter brown
- Cleaned with knife
- No macrofossils

20-21 cm
- Light brown
- Cleaned with knife

Macrofossils @ 18cm @23 cm
Not large enough to be significant

30-31 cm
- Darker brown
- Cleaned with knife
- Found small macrofossils again

40-41 cm
- Loose material
  Could not clean with knife
- Small shell fragments
- Very wet → water saturated
- Medium brown colour

<u>7th Longcore</u>
- 07-JP-02-2B (5.75-6.75m) (27-56cm)
- Medium brown
- 23cm long
- Dry/spongy sediment
- White substance at the end (23cm)
  Picture

Samples

30-31 cm

- Loose material
- Top layer scraped off
- No macrofossils
- Medium brown colour

40-41 cm

- Cleaned with knife
- Medium brown
- No macrofossils

7th Longcore

- 07-JP-02-2B (5.75-6.75m) (56-96cm)
- Definitive laminations
- Medium to dark brown
- 36cm long
- Orange substance from 2-7cm
  Picture

Samples

50-51 cm (4-5cm on this section)

- Outside of core covered in orange material
  Cleared away with knife
- Dark brown
- No macrofossils

60-61 cm (14-15cm on this section)

- Medium brown
- Cleaned with knife
- Small macrofossil found
  Pine needle → too small for sampling

70-71 cm (24-25cm on this section)

- Dark brown
  New lamination
- Cleaned with knife
- No macrofossils

80-81 cm (34-35cm on this section)

- loose material
- flaked top layer away with knife
- medium to dark brown

8th Longcore

- 07-JP-02-2C (6.75-7.75m) (0-50cm)
- Medium to dark brown
- Faint laminations
- 40cm long
  Picture

Samples

0-1 cm

- Loose material
  Top layer attempted to clear with knife
- Medium to dark brown in colour
- Macrofossils found
  Sample taken – unidentified

10-11 cm

- Medium to dark brown
- Cleaned with knife swipe
- No macrofossils

20-21 cm

- Medium to dark brown
- Cleaned with knife swipe
- No macrofossils

30-31 cm

- Medium to dark brown
- Cleaned with knife
- Macrofossils in sample
  Too small to save

8th Longcore

- 07-JP-02-2C (6.75-7.75m) (50-86cm)
- Medium brown
- Separations in material down the core
  Due to dryness
- 33 cm long
- White dry substance 29-33cm
- Small white grains @ 9.5 cm
  Picture

40-41 cm

- Loose material (end of core)
- Cleaned with knife
- Medium brown
- No macrofossils

50-51 cm

- Cleaned with knife
- Medium brown
- Macrofossil found and taken

60-61 cm

- Flaky material
- Top layer flaked off with knife
- Medium to dark brown

70-71 cm

- Cleaned with knife
- Flaky dry material
- Dark brown with white flakes
- No macrofossils

<u>9th Longcore</u>

- 07-JP-02-2D (7.75-8.75m) (0-50cm)
- Medium to dark brown
- Very moist
- 44cm long
- Very faint laminations
- 17cm-44cm many macrofossils
  Major one @ 27 cm
  Picture

Samples

0-1 cm

- Medium to dark brown
- Cleaned with knife
- No macrofossils
- End of core
  Material slightly loose

10-11 cm

- Medium brown (lamination)
- Cleaned with knife
- No macrofossils

20-21 cm

- Medium to dark brown
- Cleaned with knife swipe

Macrofossil @ 27 cm

Pine cone or large seed

30-31 cm

- Medium to dark brown
- Cleaned with knife
- Small macrofossils – not significant sample size

40-41 cm

- Medium to dark brown
- Cleaned with knife
- Small macrofossils – not significant sample size

<u>9th Longcore</u>

- 07-JP-02-2D (7.75-8.75m) (50-100cm)
- Medium to dark brown
- Faint layering
- 49 cm long
- Moist

Picture

Samples

50-51 cm

- Cleaned with knife swipe
- Spongy material
  Flaked off with knife
- Sample off of the end of the core section
- Medium brown
- No macrofossils

60-61 cm

- Cleaned with knife swipe
- Medium brown colour
- No macrofossils

70-71 cm

- Medium brown
- Cleaned with knife swipe
- Macrofossils in sample
  Too small for extracting

80-81 cm

- Cleaned with knife swipe
- Medium brown
- No macrofossils

90-91 cm

- Medium brown
- Cleaned with knife swipe
- No macrofossils

<u>10th Longcore</u>

- 07-JP-02-2E (8.75-9.75m) (0-50cm)
- Dark brown 0-13.5cm
- Tephra 13.5-17.5cm
- Medium brown 17.5-31cm
- Dark brown 31-45cm (end of core)
- Core is 45 cm long
  Picture

Samples

0-1 cm

- Cleaned with knife
- Dark brown
- Small macrofossils
  Too small to extract

10-11 cm

- Cleaned with knife
- Darker brown
- No macrofossils
- Spongy
- Located just before tephra

20-21 cm

- White streak present
- Medium brown
- Cleaned with knife
- Small macrofossils

30-31 cm

- Medium brown
- Cleaned with knife
- No macrofossils

40-41 cm

- Dark brown cleaned with knife
- No macrofossils
- Very wet material

<u>10th Longcore</u>

- 07-JP-02-2E (8.75-9.75m) (50-100cm)
- Dark brown – very organic
- Splitting of sediment throughout the core
  Picture

Samples

50-51 cm

- Dark brown
- Cleaned with knife swipe
- No macrofossils

60-61 cm

- Dark brown
- Cleaned with knife
- No macrofossils present
  Some to the right and left of the sample area

70-71 cm

- Dark brown
- Small macrofossils in sample
  Nothing of significant sample size
- Cleaned with knife swipe

80-81 cm

- Dark brown
- Cleaned with knife
- No macrofossils

90-91 cm

- Dark brown
- Cleaned with knife
- Small macrofossils in sample
  Not a significant size for extraction

11th Longcore

- 07-JP-02-2F (9.75-10.75m) (0-80cm)
- Dark brown
- Dry and spongy
- Splitting of sediment down the core
- White "sandy" material all of the core
  Mainly from 50-68.5 cm
- Sample is 68.5 cm long
  Picture

Samples

0-1 cm

- End of core
- White material in sample
- Flaked top layer away with knife
- Dark brown material
- No macrofossils
- Very dry and flakey

10-11 cm

- Dark brown material
- No macrofossils
- Dry and spongy
- Cleaned with knife

20-21 cm

- Dry and flakey
- Dark brown
- No macrofossils
- Cleaned with knife

30-31 cm

- Dark brown
- Cleaned with knife
- Not as dry and flakey
- No macrofossils

40-41 cm

- Dark brown
- White material present
- Dry and flakey
- Small macrofossils in sample
  Large one extruded just before sample was taken

50-51 cm

- Dark brown
- White material
- Cleaned with knife
- No macrofossils
- Dry
- Sample spot located on the back of the core

60-61 cm

- Very dry
- Top flaked away with knife
- White material in sample
- Macrofossils too small → in sample
- Dark brown
- Cleaned with knife

<u>1st Gravity Core</u>

- 07-JP-01-1A
- Bagged

Samples

0-0.5 cm

- Diatom sub sample only
- Added e-pure
- 3 pipets worth
- 1.3995 g

5-5.5 cm

- Diatom sub sample only
- Added e-pure
- 3 pipets worth
- 1.8064 g

10-10.5 cm

- Slightly more solid
- No water added
- Green-brown colour
- Took 1.5 cm^3 for BSi
- Took 1 cm^3 for diatoms

15-15.5 cm

- Watery
- No water added
- Sandy brown colour
- 1.5 cm^3 for BSi
- 1 cm^3 for Diatoms

20-20.5 cm

- Watery
- No water added
- Same sandy brown colour as 15 cm sample
- 1.5 cm^3 for BSi
- 1 cm^3 for Diatoms

25-25.5 cm

- More solid
- No water added
- Earthy brown
- 1.5 cm^3 for BSi
- 1 cm^3 for diatoms

30-30.5 cm

- Watery
- No water added
- Earthy brown
- 1.5 cm^3 for BSi
- 1 cm^3 for diatoms

35-35.5 cm

- Solid
- No water added
- Earth brown
- 1.5 cm^3 for BSi
- 1 cm^3 for diatoms

40-40.5 cm

- Watery
- No water added
- Earthy brown
- Looks flakey
- 1.5 cm^3 for BSi
- 1 cm^3 for diatoms

45-45.5 cm

- Watery
- No water added
- Sandy brown colour
- 1.5 cm^3 for BSi
- 1 cm^3 for diatoms

<u>12th Longcore</u>

- 07-JP-01-2A
- 70 cm long
- Distinct layering
- Majority light/sand brown
- 0-16 cm – light brown
- 16-26 cm – darker brown section
- 26-70 cm – light brown
- Dark ring @ 35 cm
- Tephra? @ 50-52 cm
- Large macrofossil @ 53-58 cm

Samples

0-1 cm

- Loose material
- Light sand brown
- No macrofossils

5-6 cm

- Loose material
- Light/sand brown
- No macrofossils

10-11 cm

- Outer layer skimmed off
- Light/ sand brown
  Small/faint dark rings
- Macrofossil found

15-16 cm

- Light/sand brown
- Macrofossil found
- Outer layer removed

20-21 cm

- Dark brown section
- Outer layer removed
- No macrofossils

25-26 cm

- Light/sand brown
  With dark brown laminations
- Outer layer removed
- No macrofossils

30-31 cm

- Light/sand brown
- Outer layer removed
- No macrofossils

35-36 cm

- Light/sand brown
  With slight dark brown discolouration
- Outer layer removed
- No macrofossils

40-41 cm

- Light/sand brown
- Not compact sediment
  Between loose and normal
- Outer layer removed
- No macrofossils

45-46 cm

- Light/sand brown
- Loosely packed
- No macrofossils

50-51 cm

- Grey
- Tephra possibly
- Outer layer removed
- No macrofossils

55-56 cm

- Light/sand brown
- Loosely packed
- Large macrofossils
  Left in core so the core can sustain its shape

60-61 cm

- Sand coloured (Looks to be sand)
- Outer layer removed
- Macrofossils taken

65-66 cm

- Light/sand brown
- Loosely packed
- Macrofossils taken

2nd Gravity Core

- 07-JP-02-GC1
- Bagged
- Could not find samples 0-6 cm

Samples

6-6.5 cm

- Green-brown colour
- Watery – too watery to sample with spatula
- 1.5 g for BSi
- 1.6 g for diatoms

8-8.5 cm

- Same colour as previous sample
- Too water
- 1.6 g for BSi
- 1.6 g for diatoms

10-10.5 cm

- Only enough to sample for BSi
- Looks watery
  Has dried up

12-12.5 cm

- More brown, less green
- Used syringe

14-14.5 cm

- Earthy brown
- 1 cm^3 for BSi and diatoms

16-16.5 cm

- Earth brown
- 1 cm^3 for BSi and diatoms

18-18.5 cm

- Earthy brown
- 1 cm^3 for BSi and diatoms

20-20.5 cm

- Medium brown
- 1 cm^3 for BSi and diatoms

22-22.5 cm

- Medium brown
- 1 cm^3 for BSi and diatoms

24-24.5 cm

- Dark brown
- 1 cm^3 for BSi and diatoms

26-26.5 cm

- Watery
- Flaky
- 1 cm^3 for BSi and diatoms

28-28.5 cm

- Light/ yellow-brown
- Small black specs
- 1 cm^3 for BSi and diatoms

30-30.5 cm

- Yellow-brown
- 1 cm^3 for BSi and diatoms

32-32.5 cm

- Yellow-brown
- 1 cm^3 for BSi and diatoms

34-34.5 cm

- Dark yellow-brown
- 1 cm^3 for BSi and diatoms

36-36.5 cm

- Light brown
- 1 cm^3 for BSi and diatoms

38-38.5 cm

- Dark yellow-brown
- 1 cm^3 for BSi and diatoms

40-40.5 cm

- Dark yellow-brown
- 1 cm^3 for BSi and diatoms

42-42.5 cm

- Dark yellow brown
- Flakey and watery
- 1 cm^3 for BSi and diatoms

44-44.5 cm

- Green-yellowish-brown
- Solid muddy look
- 1 cm^3 for BSi and diatoms

Appendix 2 – Depth Stratigraphy

07-JP-01

Previously Listed		Actual Depth
07-JP-01-1A	0-0.5 cm	0-0.5 cm
07-JP-01-1A	5-5.5 cm	5-5.5 cm
07-JP-01-1A	10-10.5 cm	10-10.5 cm
07-JP-01-1A	15-15.5 cm	15-15.5 cm
07-JP-01-1A	20-20.5 cm	20-20.5 cm
07-JP-01-1A	25-25.5 cm	25-25.5 cm
07-JP-01-1A	30-30.5 cm	30-30.5 cm
07-JP-01-1A	35-35.5 cm	35-35.5 cm
07-JP-01-1A	40-40.5 cm	40-40.5 cm
07-JP-01-1A	45-45.5 cm	45-45.5 cm
07-JP-02-2A	0-1 cm	55 cm
07-JP-02-2A	5-6 cm	60.9 cm
07-JP-02-2A	10-11 cm	66.9 cm
07-JP-02-2A	15-16 cm	72.8 cm
07-JP-02-2A	20-21 cm	78.7 cm
07-JP-02-2A	25-26 cm	84.6 cm
07-JP-02-2A	30-31 cm	90.6 cm
07-JP-02-2A	35-36 cm	96.5 cm
07-JP-02-2A	40-41 cm	102.4 cm
07-JP-02-2A	45-46 cm	108.4 cm
07-JP-02-2A	50-51 m	114.3 cm
07-JP-02-2A	55-56 cm	120.2 cm
07-JP-02-2A	60-61 cm	126.1 cm
07-JP-02-2A	65-66 cm	132.1 cm

07-JP-02-Core 1

Previously Listed		Actual Depth
07-JP-02-1A	0-1 cm	25 cm
07-JP-02-1A	10-11 cm	35 cm
07-JP-02-1A	20-21 cm	45 cm
07-JP-02-1A	30-31 cm	55.5 cm
07-JP-02-1A	40-41 cm	66 cm
07-JP-02-1A	50 cm	74 cm
07-JP-02-1A	50-51 cm	75 cm
07-JP-02-1A	60-61 cm	85 cm
07-JP-02-1A	70-71 cm	95 cm
07-JP-02-1A	80-81 cm	1.06 m

07-JP-02-1A	90-91 cm	1.15 m
Lost Sediment		10 cm
07-JP-02-1B	0-1 cm	1.250 m
07-JP-02-1B	10-11 cm	1.372 m
07-JP-02-1B	20-21 cm	1.485 m
07-JP-02-1B	30-31 cm	1.599 m
07-JP-02-1B	40-41 cm	1.715 m
07-JP-02-1B	50-51 cm	1.75 m
07-JP-02-1B	60-61 cm	1.86 m
07-JP-02-1B	70-71 cm	1.97 m
07-JP-02-1B	80-81 cm	2.08 m
07-JP-02-1B	90-91 cm	2.19 m
Lost Sediment		6 cm
07-JP-02-1C	0-1 cm	2.25 m
07-JP-02-1C	10-11 cm	2.364 m
07-JP-02-1C	20-21 cm	2.478 m
07-JP-02-1C	30-31 cm	2.592 m
07-JP-02-1C	40-41 cm	2.706 m
07-JP-02-1C	50-51 cm	2.75 m
07-JP-02-1C	60-61 cm	2.865 m
07-JP-02-1C	70-71 cm	2.98 m
07-JP-02-1C	80-81 cm	3.095 m
07-JP-02-1C	90-91 cm	3.21 m
Lost Sediment		4 cm
07-JP-02-1D	0-1 cm	3,25 m
07-JP-02-1D	10-11 cm	3.359 m
07-JP-02-1D	20-21 cm	3.467 m
07-JP-02-1D	30-31 cm	3.576 m
07-JP-02-1D	40-41 cm	3.685 m
07-JP-02-1D	50-51 cm	3.75 m
07-JP-02-1D	60-61 cm	3.856 m
07-JP-02-1D	70-71 cm	3.962 m
07-JP-02-1D	80-81 cm	4.067 m
07-JP-02-1D	90-91 cm	4.173 m
Lost Sediment		7.7 cm
07-JP-02-1E	0-1 cm	4.25 m
07-JP-02-1E	10-11 cm	4.356 m
07-JP-02-1E	20-21 cm	4.462 m
07-JP-02-1E	30-31 cm	4.568 m
07-JP-02-1E	40-41 cm	4.674 m
07-JP-02-1E	50-51 cm	4.78 m

07-JP-02-1E	60-61 cm	4.886 m
Lost Sediment		11.4 cm

07-JP-02-Core 2

Previously Listed		Actual Depth
07-JP-02-2A	0-1 cm	50 cm
07-JP-02-2A	10-11 cm	62.5 cm
07-JP-02-2A	20-21 cm	75 cm
07-JP-02-2A	30-31 cm	87.5 cm
07-JP-02-2A	40-41 cm	1.0 m
Lost Sediment		30 cm
07-JP-02-2B	30-31 cm	1.308 m
07-JP-02-2B	40-41 cm	1.434 m
07-JP-02-2B	50-51 cm	1.608 m
07-JP-02-2B	60-61 cm	1.727 m
07-JP-02-2B	70-71 cm	1.847 m
07-JP-02-2B	80-81 cm	1.966 m
Lost Sediment		3.4 cm
07-JP-02-2C	0-1 cm	2.0 m
07-JP-02-2C	10-11 cm	2.124 m
07-JP-02-2C	20-21 cm	2.247 m
07-JP-02-2C	30-31 cm	2.370 m
07-JP-02-2C	40-41 cm	2.5 m
07-JP-02-2C	50-51 cm	2.613 m
07-JP-02-2C	60-61 cm	2.725 m
07-JP-02-2C	70-71 cm	2.838 m
Lost Sediment		16.2 cm
07-JP-02-2D	0-1 cm	3.0 m
07-JP-02-2D	10-11 cm	3.118 m
07-JP-02-2D	20-21 cm	3.235 m
07-JP-02-2D	30-31 cm	3.353 m
07-JP-02-2D	40-41 cm	3.471 m
07-JP-02-2D	50-51 cm	3.5 m
07-JP-02-2D	60-61 cm	3.603 m
07-JP-02-2D	70-71 cm	3.706 m
07-JP-02-2D	80-81 cm	3.809 m
07-JP-02-2D	90-91 cm	3.912 m
Lost Sediment		8.8 cm
07-JP-02-2E	0-1 cm	4.0 m
07-JP-02-2E	10-11 cm	4.109 m

07-JP-02-2E	20-21 cm	4.217 m
07-JP-02-2E	30-31 cm	4.326 m
07-JP-02-2E	40-41 cm	4.435 m
07-JP-02-2E	50-51 cm	4.5 m
07-JP-02-2E	60-61 cm	4.604 m
07-JP-02-2E	70-71 cm	4.708 m
07-JP-02-2E	80-81 cm	4.813 m
07-JP-02-2E	90-91 cm	4.917 m
Lost Sediment		8.3 cm
07-JP-02-2F	0-1 cm	5.0 m
07-JP-02-2F	10-11 cm	5.123 m
07-JP-02-2F	20-21 cm	5.246 m
07-JP-02-2F	30-31 cm	5.369 m
07-JP-02-2F	40-41 cm	5.492 m
07-JP-02-2F	50-51 cm	5.615 m
07-JP-02-2F	60-61 cm	5.739 m

Appendix 3 – Sediment Weight Used in Biogenic Silica Analyses

BSI #1			
Bottle #	Sample		Weight (mg)
1	07-JP-02-1A	0-1 cm	20.6
2	07-JP-02-1A	10-11 cm	20.0
3	07-JP-02-1A	20-21 cm	20.2
4	07-JP-02-1A	30-31 cm	20.5
5	07-JP-02-1A	40-41 cm	20.2
6	07-JP-02-1A	50 cm	19.9
7	07-JP-02-1A	50-51 cm	20.6
8	07-JP-02-1A	60-61 cm	20.2
9	07-JP-02-1A	70-71 cm	20.0
10	07-JP-02-1A	80-81 cm	20.3
11	07-JP-02-1A	90-91 cm	20.4
12	07-JP-02-1B	0-1 cm	19.9
13	07-JP-02-1B	10-11 cm	20.3
14	07-JP-02-1B	20-21 cm	19.7
15	07-JP-02-1B	30-31 cm	20.3
16	07-JP-02-1B	40-41 cm	20.5
17	07-JP-02-1B	50-51 cm	20.0
18	07-JP-02-1B	60-61 cm	19.9
19	07-JP-02-1B	70-71 cm	20.0
20	07-JP-02-1B	80-81 cm	19.7
21	07-JP-02-1B	90-91 cm	20.5
22	07-JP-02-1A	10-11 cm	19.8
23	07-JP-02-1A	40-41 cm	19.8
24	07-JP-02-1A	60-61 cm	19.8
25	07-JP-02-1A	90-91 cm	20.8
26	07-JP-02-1B	10-11 cm	20.1
27	07-JP-02-1B	50-51 cm	20.2
28	07-JP-02-1B	90-91 cm	20.3

BSI #2			
Bottle #	Sample		Weight (mg)
1	07-JP-02-1C	0-1 cm	20.8
2	07-JP-02-1C	10-11 cm	20.3
3	07-JP-02-1C	20-21 cm	20.1
4	07-JP-02-1C	30-31 cm	20.1
5	07-JP-02-1C	40-41 cm	20.2
6	07-JP-02-1C	50-51 cm	19.9
7	07-JP-02-1C	60-61 cm	20.7
8	07-JP-02-1C	70-71 cm	20.1
9	07-JP-02-1C	80-81 cm	20.0
10	07-JP-02-1C	90-91 cm	20.3
11	07-JP-02-1D	0-1 cm	19.9
12	07-JP-02-1D	10-11 cm	20.7
13	07-JP-02-1D	20-21 cm	19.7
14	07-JP-02-1D	30-31 cm	19.9
15	07-JP-02-1D	40-41 cm	20.1
16	07-JP-02-1D	50-51 cm	20.8
17	07-JP-02-1D	60-61 cm	19.8
18	07-JP-02-1D	70-71 cm	20.6
19	07-JP-02-1D	80-81 cm	19.7
20	07-JP-02-1D	90-91 cm	20.1
21	07-JP-02-1E	0-1 cm	20.8
22	07-JP-02-1E	10-11 cm	20.5
23	07-JP-02-1E	20-21 cm	19.9
24	07-JP-02-1E	30-31 cm	20.9
25	07-JP-02-1C	0-1 cm	20.5
26	07-JP-02-1D	10-11 cm	19.8
27	07-JP-02-1D	70-71 cm	20.1
28	07-JP-02-1E	30-31 cm	19.9

BSI #3			
Bottle #	Sample		Weight (mg)
1	07-JP-02-1E	40-41 cm	20.0
2	07-JP-02-1E	50-51 cm	19.9
3	07-JP-02-1E	60-61 cm	19.9
4	07-JP-02-2A	0-1 cm	20.1
5	07-JP-02-2A	10-11 cm	20.0
6	07-JP-02-2A	20-21 cm	20.0
7	07-JP-02-2A	30-31 cm	20.4
8	07-JP-02-2A	40-41 cm	20.5
9	07-JP-02-2B	30-31 cm	20.0
10	07-JP-02-2B	40-41 cm	20.0
11	07-JP-02-2B	50-51 cm	20.1
12	07-JP-02-2B	60-61 cm	20.7
13	07-JP-02-2B	70-71 cm	19.9
14	07-JP-02-2B	80-81 cm	19.9
15	07-JP-02-2C	0-1 cm	19.8
16	07-JP-02-2C	10-11 cm	20.3
17	07-JP-02-2C	20-21 cm	20.9
18	07-JP-02-2C	30-31 cm	19.8
19	07-JP-02-2C	40-41 cm	20.0
20	07-JP-02-2C	50-51 cm	20.6
21	07-JP-02-2C	60-61 cm	20.2
22	07-JP-02-2C	70-71 cm	20.5
23	07-JP-02-2D	0-1 cm	20.1
24	07-JP-02-2D	10-11 cm	20.1
25	07-JP-02-2A	10-11 cm	20.1
26	07-JP-02-2B	40-41 cm	20.3
27	07-JP-02-2C	10-11 cm	19.9
28	07-JP-02-2D	10-11 cm	20.0

BSI #4			
Bottle #	Sample		Weight (mg)
1	07-JP-02-2D	20-21 cm	19.9
2	07-JP-02-2D	30-31 cm	20.1
3	07-JP-02-2D	40-41 cm	20.3
4	07-JP-02-2D	50-51 cm	20.0
5	07-JP-02-2D	60-61 cm	20.1
6	07-JP-02-2D	70-71 cm	19.9
7	07-JP-02-2D	80-81 cm	20.1
8	07-JP-02-2D	90-91 cm	20.1
9	07-JP-02-2E	0-1 cm	20.1
10	07-JP-02-2E	10-11 cm	20.0
11	07-JP-02-2E	20-21 cm	20.4
12	07-JP-02-2E	30-31 cm	20.0
13	07-JP-02-2E	40-41 cm	20.1
14	07-JP-02-2E	50-51 cm	20.3
15	07-JP-02-2E	60-61 cm	20.6
16	07-JP-02-2E	70-71 cm	20.0
17	07-JP-02-2E	80-81 cm	19.9
18	07-JP-02-2E	90-91 cm	20.0
19	07-JP-02-2F	0-1 cm	20.0
20	07-JP-02-2F	10-11 cm	20.0
21	07-JP-02-2F	20-21 cm	19.8
22	07-JP-02-2F	30-31 cm	19.8
23	07-JP-02-2F	40-41 cm	20.5
24	07-JP-02-2F	50-51 cm	20.0
25	07-JP-02-2F	60-61 cm	20.2
26	07-JP-02-2D	30-31 cm	20.1
27	07-JP-02-2E	30-31 cm	20.9
28	07-JP-02-2F	30-31 cm	20.3

BSI #5			
Bottle #	Sample		Weight (mg)
1	07-JP-01-1A	10-10.5 cm	20.0
2	07-JP-01-1A	15-15.5 cm	20.0
3	07-JP-01-1A	20-20.5 cm	20.3
4	07-JP-01-1A	25-25.5 cm	20.2
5	07-JP-01-1A	30-30.5 cm	20.1
6	07-JP-01-1A	35-35.5 cm	20.6
7	07-JP-01-1A	40-40.5 cm	20.3
8	07-JP-01-1A	45-45.5 cm	21.0
9	07-JP-01-2A	0-1 cm	20.3
10	07-JP-01-2A	5-6 cm	20.1
11	07-JP-01-2A	10-11 cm	20.1
12	07-JP-01-2A	15-16 cm	20.0
13	07-JP-01-2A	20-21 cm	20.2
14	07-JP-01-2A	25-26 cm	20.0
15	07-JP-01-2A	30-31 cm	20.0
16	07-JP-01-2A	35-36 cm	20.0
17	07-JP-01-2A	40-41 cm	20.8
18	07-JP-01-2A	45-46 cm	20.0
19	07-JP-01-2A	50-51 cm	20.0
20	07-JP-01-2A	55-56 cm	20.2
21	07-JP-01-2A	60-61 cm	20.0
22	07-JP-01-2A	65-66 cm	20.1
23	07-JP-01-1A	30-30.5 cm	20.1
24	07-JP-01-2A	30-31 cm	20.2

BSI #6			
Bottle #	Sample		Weight (mg)
1	07-JP-02-GC1	6-6.5 cm	20.3
2	07-JP-02-GC1	8-8.5 cm	20.5
3	07-JP-02-GC1	10-10.5 cm	20.3
4	07-JP-02-GC1	12-12.5 cm	20.3
5	07-JP-02-GC1	14-14.5 cm	20.3
6	07-JP-02-GC1	16-16.5 cm	20.3
7	07-JP-02-GC1	18-18.5 cm	20.1
8	07-JP-02-GC1	20-20.5 cm	20.1
9	07-JP-02-GC1	22-22.5 cm	20.2
10	07-JP-02-GC1	24-24.5 cm	20.2
11	07-JP-02-GC1	26-26.5 cm	20.2
12	07-JP-02-GC1	28-28.5 cm	19.9
13	07-JP-02-GC1	30-30.5 cm	20.0
14	07-JP-02-GC1	32-32.5 cm	20.1
15	07-JP-02-GC1	34-34.5 cm	20.0
16	07-JP-02-GC1	36-36.5 cm	19.8
17	07-JP-02-GC1	38-38.5 cm	20.0
18	07-JP-02-GC1	40-40.5 cm	20.6
19	07-JP-02-GC1	42-42.5 cm	20.5
20	07-JP-02-GC1	44-44.5 cm	20.1
21	07-JP-02-1D	60-61 cm	20.9
22	07-JP-02-1D	80-81 cm	20.2
23	07-JP-02-2D	80-81 cm	20.5
24	07-JP-02-2E	0-1 cm	20.0
25	07-JP-02-1C	80-81 cm	20.8

Appendix 4 – Weight Percent Biogenic Silica

	Lake Name	Depth	Wt. % BSi
1	07 - JP - 02	0 - 1 cm	6.0
2	07 - JP - 02	10 - 11cm	9.2
3	07 - JP - 02	20 - 21cm	5.8
4	07 - JP - 02	30 - 31cm	8.5
5	07 - JP - 02	40 - 41cm	5.8
6	07 - JP - 02	50cm	7.1
7	07 - JP - 02	50 - 51cm	6.3
8	07 - JP - 02	60 - 61cm	8.5
9	07 - JP - 02	70 - 71cm	8.0
10	07 - JP - 02	80 - 81cm	12.1
11	07 - JP - 02	90 - 91cm	10.5
12	07 - JP - 02	0 - 1cm	12.8
13	07 - JP - 02	10 - 11cm	10.1
14	07 - JP - 02	20 - 21cm	10.2
15	07 - JP - 02	30 - 31cm	9.6
16	07 - JP - 02	40 - 41cm	9.4
17	07 - JP - 02	50 - 51cm	9.7
18	07 - JP - 02	60 - 61cm	6.9
19	07 - JP - 02	70 - 71cm	5.4
20	07 - JP - 02	80 - 81cm	5.8
21	07 - JP - 02	90 - 91cm	6.6
22	07 - JP - 02	10 - 11cm	12.4
23	07 - JP - 02	40 - 41 cm	9.2
24	07 - JP - 02	60 - 61cm	9.4
25	07 - JP - 02	90 - 91cm	14.1
26	07 - JP - 02	10 - 11cm	7.6
27	07 - JP - 02	50 - 51cm	7.5
28	07 - JP - 02	90 - 91cm	5.7

	Lake Name	Depth	Wt. % BSi
1	07 - JP - 02	0 - 1 cm	4.9
2	07 - JP - 02	10 - 11 cm	6.9
3	07 - JP - 02	20 - 21 cm	3.0
4	07 - JP - 02	30 - 31 cm	5.8
5	07 - JP - 02	40 - 41 cm	5.2
6	07 - JP - 02	50 - 51 cm	4.2
7	07 - JP - 02	60 - 61 cm	4.3
8	07 - JP - 02	70 - 71 cm	7.2
9	07 - JP - 02	80 - 81 cm	11.3
10	07 - JP - 02	90 - 91 cm	7.3
11	07 - JP - 02	0 - 1 cm	6.2
12	07 - JP - 02	10 - 11 cm	4.7
13	07 - JP - 02	20 - 21 cm	3.4
14	07 - JP - 02	30 - 31 cm	2.4
15	07 - JP - 02	40 - 41 cm	1.7
16	07 - JP - 02	50 - 51 cm	1.8
17	07 - JP - 02	60 - 61 cm	3.6
18	07 - JP - 02	70 - 71 cm	3.2
19	07 - JP - 02	80 - 81 cm	2.0
20	07 - JP - 02	90 - 91 cm	3.1
21	07 - JP - 02	0 - 1 cm	2.7
22	07 - JP - 02	10 - 11 cm	2.6
23	07 - JP - 02	20 - 21 cm	3.1
24	07 - JP - 02	30 - 31 cm	3.0
25	07 - JP - 02	0 - 1 cm	2.6
26	07 - JP - 02	10 - 11 cm	2.5
27	07 - JP - 02	70 - 71 cm	3.1
28	07 - JP - 02	30 - 31 cm	1.8

	Lake Name	Depth	Wt. % BSi
1	07JP02	40 - 41 cm	4.8
2	07JP02	50 - 51 cm	3.5
3	07JP02	60 - 61 cm	1.8
4	07JP02	0 - 1 cm	9.2
5	07JP02	10 - 11 cm	7.2
6	07JP02	20 - 21 cm	9.7
7	07JP02	30 - 31 cm	10.3
8	07JP02	40 - 41 cm	7.2
9	07JP02	30 - 31 cm	11.6
10	07JP02	40 - 41 cm	11.9
11	07JP02	50 - 51 cm	10.7
12	07JP02	60 - 61 cm	8.7
13	07JP02	70 - 71 cm	10.5
14	07JP02	80 - 81 cm	8.3
15	07JP02	0 - 1 cm	7.5
16	07JP02	10 - 11 cm	7.5
17	07JP02	20 - 21 cm	5.9
18	07JP02	30 - 31 cm	8.9
19	07JP02	40 - 41 cm	5.2
20	07JP02	50 - 51 cm	8.4
21	07JP02	60 - 61 cm	9.3
22	07JP02	70 - 71 cm	6.5
23	07JP02	0 - 1 cm	8.6
24	07JP02	10 - 11 cm	6.5
25	07JP02	10 - 11 cm	4.9
26	07JP02	40 - 41 cm	8.6
27	07JP02	10 - 11 cm	6.8
28	07JP02	10 - 11 cm	5.3

	Lake Name	Depth	Wt. % BSi
1	07JP02	20 - 21 cm	6.9
2	07JP02	30 - 31 cm	7.3
3	07JP02	40 - 41 cm	6.2
4	07JP02	50 - 51 cm	6.5
5	07JP02	60 - 61 cm	5.2
6	07JP02	70 - 71 cm	6.6
7	07JP02	80 - 81 cm	11.6
8	07JP02	90 - 91 cm	10.9
9	07JP02	0 - 1 cm	8.4
10	07JP02	10 - 11 cm	9.5
11	07JP02	20 - 21 cm	6.9
12	07JP02	30 - 31 cm	5.3
13	07JP02	40 - 41 cm	3.8
14	07JP02	50 - 51 cm	5.0
15	07JP02	60 - 61 cm	3.9
16	07JP02	70 - 71 cm	3.1
17	07JP02	80 - 81 cm	9.3
18	07JP02	90 - 91 cm	5.1
19	07JP02	0 - 1 cm	4.9
20	07JP02	10 - 11 cm	4.2
21	07JP02	20 - 21 cm	5.0
22	07JP02	30 - 31 cm	6.5
23	07JP02	40 - 41 cm	6.5
24	07JP02	50 - 51 cm	5.2
25	07JP02	60 - 61 cm	4.9
26	07JP02	30 - 31 cm	6.2
27	07JP02	30 - 31 cm	3.7
28	07JP02	30 - 31 cm	4.1

Lake Name	Depth	Wt. % BSi
07-JP-02 GC1	6 - 6.5 cm	3.8
07-JP-02	8 - 8.5 cm	4.4
07-JP-02	10 - 10.5 cm	3.8
07-JP-02	12 - 12.5 cm	4.9
07-JP-02	14 - 14.5 cm	4.8
07-JP-02	16 - 16.5 cm	6.1
07-JP-02	18 - 18.5 cm	6.7
07-JP-02	20 - 20.5 cm	9.6
07-JP-02	22 - 22.5 cm	10.4
07-JP-02	24 - 24.5 cm	5.9
07-JP-02	26 - 26.5 cm	10.0
07-JP-02	28 - 28.5 cm	10.3
07-JP-02	30 - 30.5 cm	3.1
07-JP-02	32 - 32.5 cm	3.3
07-JP-02	34 - 34.5 cm	3.8
07-JP-02	36 - 36.5 cm	4.0
07-JP-02	38 - 38.5 cm	4.8
07-JP-02	40 - 40.5 cm	5.0
07-JP-02	42 - 42.5 cm	7.6
07-JP-02	44 - 44.5 cm	8.0
07-JP-02	60 - 61 cm	4.4
07-JP-02	80 - 81 cm	1.8
07-JP-02	80 - 81 cm	10.5
07-JP-02	0 - 1 cm	9.9
07-JP-02	80 - 81 cm	10.2

	Lake Name	Depth	Wt. % BSi
1	07 - JP - 01	10 - 10.5 cm	6.8
2	07 - JP - 01	15 - 15.5 cm	1.7
3	07 - JP - 01	20 - 20.5 cm	1.4
4	07 - JP - 01	25 - 25.5 cm	2.3
5	07 - JP - 01	30 - 30.5 cm	2.4
6	07 - JP - 01	35 - 35.5 cm	1.9
7	07 - JP - 01	40 - 40.5 cm	2.1
8	07 - JP - 01	45 - 45.5 cm	1.6
9	07 - JP - 01	0 - 1 cm	2.1
10	07 - JP - 01	5 - 6 cm	1.7
11	07 - JP - 01	10 - 11 cm	3.3
12	07 - JP - 01	15 - 16 cm	1.8
13	07 - JP - 01	20 - 21 cm	2.5
14	07 - JP - 01	25 - 26 cm	1.9
15	07 - JP - 01	30 - 31 cm	0.8
16	07 - JP - 01	35 - 36 cm	1.0
17	07 - JP - 01	40 - 41 cm	1.2
18	07 - JP - 01	45 - 46 cm	1.6
19	07 - JP - 01	50 - 51 cm	3.5
20	07 - JP - 01	55 - 56 cm	0.4
21	07 - JP - 01	60 - 61 cm	0.9
22	07 - JP - 01	65 - 66 cm	0.8
23	07 - JP - 01	30 - 30.5 cm	2.7
24	07 - JP - 01	30 - 31 cm	1.4

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