ALASKA ENERGY AUTHORITY

May 17, 2016

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: Susitna-Watana Hydroelectric Project, FERC Project No. 14241-000; Transmittal of Study Implementation Report for Study 13.5 (Cultural Resources Study) and Request for Privileged Treatment

Dear Secretary Bose:

As required by the Federal Energy Regulatory Commission's (Commission or FERC) Integrated Licensing Process regulations, 18 C.F.R. § 5.15(c)(2), and the Commission's plan and schedule issued in the above-referenced licensing proceeding on December 2, 2015, the Alaska Energy Authority (AEA) held a series of Initial Study Plan (ISR) meetings for the proposed licensing of the Susitna-Watana Hydroelectric Project, FERC No. 14241 (Project) between March 22 and 30, 2016. These meetings addressed each of the 58 individual plans included in the Commission-approved Study Plan for the licensing of the Project. On April 25, 2016, AEA filed with the Commission summaries from each of the ISR meetings and follow-up documents in response to action items agreed to during or after the ISR meetings.

AEA hereby submits an additional follow-up document agreed to during the March 30, 2016 ISR meeting: (1) Holocene Landscape and Paleoenvironments Technical Memorandum; and (2) Report on Ahtna Ethnogeography Investigations. These study reports are attached to the enclosed Study Implementation Report (SIR) for the Cultural Resources Study (Study 13.5).

AEA notes that Attachment 2 to the enclosed SIR is being filed as a "privileged" document. **The Report on Ahtna Ethnogeography Investigations contains sensitive information about the nature and location of historic properties which is not to be disclosed to the public.[1] Accordingly, pursuant to 18 C.F.R. § 388.112(b), AEA hereby requests that Attachment 2 be accorded privileged treatment and placed within the Commission's non-public files.[2]**

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[1] *See* 18 C.F.R. § 5.6(d)(3)(x)(C); 36 C.F.R. § 800.11(c).

[2] *See* 5 U.S.C. § 552; 18 C.F.R. § 388.107.

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If you have any questions or need additional information, please contact me at (907) 771-3955. Thank you.

Sincerely,

Betsy McGregor
Environmental Manager
Alaska Energy Authority

Attachments

cc: Distribution List

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Cultural Resources Study
Study Plan Section 13.5

2014-2015 Study Implementation Report

Prepared for

Alaska Energy Authority

Prepared by

URS Alaska, LLC
Gwanshii
Ahtna, Inc.
Northern Land Use Research Alaska, LLC
Ahtna Heritage Foundation
Ahtna people of Cantwell
University of Alaska Fairbanks
USGS

May 2016

RESTRICTED DATA NOTICE

The locations of cultural resources given in this report are provided to facilitate environmental and engineering planning efforts only. Under the provisions of the Archaeological Resources Protection Act and the National Historic Preservation Act, site location information is restricted in distribution; public disclosure of such information is exempt from requests under federal and state freedom of information laws. This draft report is not a public document. It is submitted in fulfillment of the Standard Stipulations and Conditions outlined in the Alaska Office of History and Archaeology (OHA) Permit No.2014-21. The information contained in this report is for release only to the State Historic Preservation Officer, the Bureau of Land Management, Alaska Energy Authority, the Federal Energy Regulatory Commission, and other appropriate consulting parties. Recipients of this information are requested to maintain the confidentiality of this report and all information contained herein.

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LIST OF ACRONYMS

Abbreviation	Definition
AEA	Alaska Energy Authority
APE	Area of Potential Effects
CIRWG	Cook Inlet Region Working Group
FERC	Federal Energy Regulatory Commission
HPMP	Historic Properties Management Plan
ILP	Integrated Licensing Process
ISR	Initial Study Report (AEA 2014)
RSP	Revised Study Report
SPD	Study Plan Determination
TCP	Traditional Cultural Properties

1. INTRODUCTION

This Study Implementation Report, Section 13.5 of the Revised Study Plan (RSP) approved by the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241 focuses on systematically inventorying cultural resources within the Area of Potential Effects (APE), evaluating the National Register eligibility of inventoried cultural resources within the APE that may be affected by the Project, and assessing Project-related effects on National Register-eligible historic properties within the APE. A summary of the development of this study, together with the Alaska Energy Authority's (AEA) implementation of it through the 2013 study season, appears in Part A, Section 1 of the Initial Study Report (ISR) filed with FERC in June 2014. As required under FERC's regulations for the Integrated Licensing Process (ILP), the ISR describes AEA's "overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule" (18 CFR 5.15(c)(1)).

Since filing the ISR in June 2014, AEA has continued to implement the FERC-approved plan for the Cultural Resources Study. For example the study team conducted the following activities:

- On October 22, 2014, AEA held an ISR meeting for the Cultural Resources Study.
- The study team completed its assembly of Ahtna ethnographic and linguistic information to help inventory and evaluate historic properties.
- The study team completed the Holocene Landscape and Paleoenvironment Study.
- During a cultural resource site inventory on Cook Inlet Region Working Group (CIRWG) lands, the study team inventoried approximately 30 archaeological sites.
- The study team completed a 2014 year-end report for the Bureau of Land Management and the Alaska Office of History and Archaeology.
- On March 30, 2016, AEA held a second ISR meeting for the Cultural Resources Study.

In furtherance of the FERC's Study Plan Determination (SPD) expected in 2016, this report describes AEA's overall progress in implementing two components of the Cultural Resources Study since 2013. Rather than a comprehensive reporting of all field work, data collection and data analysis since the beginning of AEA's study program, this report is intended to supplement and update the information presented in Part A of the ISR for the Cultural Resources Study.

The Cultural Resources Study has three components: inventory and evaluation of archeological and historic resources; paleoenvironment; and ethnogeography. This Study Implementation Report describes the methods, results and discussion for the latter two components as Attachment 1, *Holocene Landscape and Paleoenvironments Technical Memorandum* and Attachment 2, *Report on Ahtna Ethnogeography Investigation*, respectively.

2. STUDY OBJECTIVES

The goals of the Study Plan are to systematically inventory cultural resources within the APE (36CFR 800.4(b)), evaluate the National Register eligibility of inventoried cultural resources within the APE that may be affected by the Project (36 CFR § 800.4(c)), and assess Project-related effects on National Register-eligible historic properties within the APE (36 CFR § 800.5).

Specific objectives are to:

- Consult with the SHPO, BLM, and Alaska Native entities during implementation of the cultural resources survey
- Inventory cultural resources within the APE
- Evaluate National Register eligibility of cultural resources within the APE that may be affected by the Project
- Determine the potential Project-related effects on National Register-eligible historic properties within the APE
- Develop information needed to prepare a Historic Properties Management Plan (HPMP) for the Project

The Traditional Cultural Properties (TCP) study will be informed through the ethnogeographic study, which has as its goals the identification, inventory, and evaluation of landscape features and resources within the APE that have been and continue to be important to the Native people. The objective is to use ethnographic landscape and place name data to help identify TCPs according to procedures set forth under 36 CFR Part 800, and determine their significance according to National Register criteria (36 CFR § 60.4).

The ethnogeographic study addresses the following topics, with emphasis on Ahtna tribal practices, supplemented by information on Dena'ina and Lower Tanana tribal practices as appropriate:

- Land use patterns in the study area, including the seasonal migration patterns of the late 19th and early 20th centuries, and how they relate to the system of trails, trap lines, hunting and fishing sites, winter villages, and religious sites
- Types of wild resources harvested and traditional ecological knowledge about historic plant, animal, and fish populations in the area
- Traditional stewardship (i.e., traditional management practices)
- Contemporary values associated with the landscape
- Transcription and translation of language texts that pertain to the Project APE
- Hydrological concepts embedded in place names, directional system, and landscape narratives

3. STUDY AREA

The study area for this study (which is the APE for the Project) is set forth in RSP Section 13.5.3, and is composed of an area of direct effect and an area of indirect effect—the geographic region in which the character or use of historic properties may be affected directly or indirectly by construction and operation of the Project. As proposed in the ISR Part C and summarized in

ISR Part D Section 7, AEA proposed to modify the Study Area by eliminating the Chulitna Corridor from further study and adding the Denali East Option as an alternate corridor (Figure 3-1). The APE for both direct and indirect effects is identified using several types of information, including Project engineering (transportation corridors and potential visitor infrastructure), known or likely human use patterns, and topographic features that may act as boundaries to visitor travel beyond the project footprint.

To characterize the paleoenvironment, lake core samples were collected from Clarence, Deadman, Big and Sally Lakes (Figure 3-2).

The Ahtna ethnogeography investigation included contemporary interviews with Ahtna Natives whose traditional territory included the area bounded by the Susitna River on the east and south, the Alaska Range on the north and the Parks Highway on the west (Figure 3-3). The area includes the western portion of traditional territory of the *Hwtsaay Hwt'aene* or 'small timber people', an Ahtna band whose homeland includes the upper Susitna River drainage above Devils Canyon, and the upper Nenana River. Archaeological and linguistic evidence indicates the *Hwtsaay Hwt'aene* have inhabited much of this area for at least a millennium. This area also encompasses the periphery of the traditional territory of the Dena'ina Athabascans, including part of the Talkeetna Mountains and middle Susitna River (de Laguna and McClellan 1981; Kari and Fall 2003; Kari 2008).

4. METHODS AND VARIANCES

The methods described in the RSP were implemented and are further detailed in the attachments to this report.

4.1. Paleoenvironment

Lakes and ponds can contain a paleoenvironmental record spanning hundreds and thousands of years. Under stable conditions, their surfaces collect airborne sediments that then sink and ultimately settle on the basin floor. By sampling lacustrine (lake) bottom sediments it is possible to characterize past environmental conditions during the Holocene and very late Pleistocene. Lake sediments typically contain pollen spores, volcanic ash (tephra), wind-blown silt (known as aeolian silt, or loess), and sand. Insect exoskeletons, aquatic microorganisms, vegetation, and other botanical and faunal remains in various states of preservation contribute to basin sediments. Through time, the resulting lacustrine beds preserve a record of the area's sedimentation history and vegetation succession. Accurate information on the study area's paleoenvironment helps place the archaeological record in its proper context, and can contribute temporal depth to analyses of contemporary flora and fauna. Lake core samples were collected from Clarence, Deadman, Big and Sally lakes and analyzed to characterize the Paleoenvironment as described in RSP Section 13.5.4.4. The methods for collecting and analyzing the lake core samples, as well as the variances from the Study Plan, are further detailed in Section 4 of Attachment 1 of this report.

4.1. Ethnogeography

AEA implemented the methods for the Ahtna ethnogeography investigations as described in the Study Plan (RSP Section 13.5.4.8) and further detailed in Attachment 2, with no variances. The Dena'ina Athabaskan ethnogeographic investigation has not yet been implemented. Information was collected to help inventory and evaluate cultural resources documented by the archaeological investigation, as well as to determine whether any TCPs are present within the direct or indirect APE. Archival and oral history sources were relied upon for the ethnogeography investigation; site investigations were not conducted except for an aerial reconnaissance of the study area for general orientation. Archival research focused upon pertinent written and photographic records, and transcription, translation, and analysis of oral history tapes from decades past – some in the Ahtna language, and some in English. Contemporary interviews with Ahtna Natives whose traditional territory included the study area were also conducted.

5. RESULTS

The results for the Paleoenvironment and Ahtna ethnogeography study components are detailed in the attachments to this report.

5.1. Paleoenvironment

The results of this effort are reported in the *Holocene Landscape and Paleoenvironments Technical Memorandum* (Attachment 1), including analysis of:

- chronology and sediment stratigraphy,
- tephra identification and correlation,
- sediment geochemistry,
- palynology and vegetation reconstruction, and
- diatoms.

5.1. Ethnogeography

Section 5 of *Report on Ahtna Ethnogeography Investigation* (Attachment 2) provides an overview of both the Ahtna culture up to World War II and history of the Western Ahtna to provide context for assessing potential TCPs. The history is organized around four events that have shaped Western Ahtna cultural identity and are rooted in the traditional land use of the upper Susitna Basin: 1) consolidation of Western Ahtna territorial boundaries, 2) the fur trade, 3) settlement at Valdez Creek, and 4) resettlement in Cantwell. Place names, routes and trails are included throughout the summary.

6. DISCUSSION

Progress has been made in achieving the objectives of the Cultural Resources Study (13.5).

5.1. Paleoenvironment

One of the goals of this study component is to correlate tephra found in lake cores to tephra found on the landscape to help better constrain the ages of terrestrial deposits. There are three widespread tephra deposits that have been routinely recognized during cultural resource investigations conducted in the Susitna River valley. From oldest to youngest, they are the informally named Oshetna, Watana, and Devil tephras. Based on the data gathered, it appears likely that all four lakes contain the same Watana tephra. These lakes started forming by roughly 14,000 to 12,000 cal yrs BP, providing limiting ages on deglaciation in the region. This is 1,000 to 3,000 years earlier than previous reconstructions, but not unexpected. Further details on the tephra and descriptions of the climate and vegetation from the pollen record can be found in Section 6 of Attachment 1.

A major objective of this study component was to begin to outline the environmental contexts for understanding changes in the archaeological record of the upper and middle Susitna River Valley. The analysis described in Attachment 1 provides a major step toward understanding the evolution of Holocene landscapes and provides a context for human responses to ecological and environmental change over the past 14,000 years.

5.1. Ethnogeography

The data presented in Attachment 2 provides a historical and cultural context within which to evaluate the significance of archaeological resources, to help identify potential TCPs according to procedures set forth under 36 CFR Part 800, and to determine their significance. The research revealed a unique cultural landscape composed of memory and personal experience that is tightly integrated into the identity, emotions, and history of the *Hwtsaay Hwt'aene.* The data presented in this report demonstrate that:

1. The study area was the traditional territory of the *Hwtsaay Hwt'aene*. Evidence from the archaeological record, ethnographic data, archival data, and place names data indicates that the *Hwtsaay Hwt'aene* have occupied the area for at least a millennium.
2. All Ahtna recognize the area as the traditional territory of the *Hwtsaay Hwt'aene*.
3. A majority of the descendants of the *Hwtsaay Hwt'aene* live in Cantwell and continue to have a strong attachment to their traditional territory.
4. This attachment is demonstrated through the traditional pursuits of hunting, fishing, and gathering, and people's knowledge of the land.
5. Contemporary uses are rooted in the past.

7. CONCLUSIONS

In summary, significant progress has been made in 2014-2015. The Ahtna ethnogeographic investigation portion of the study has been completed. The Ahtna language place name database and atlas has been integrated into site location models. This data will be used in the future to help evaluate historic properties, particularly TCPs. The paleoenvironment has been successfully characterized through the analysis of lake core samples collected from four lakes in the study area. The data will be useful in evaluating prehistoric cultural resources in their temporal and ecological context.

8. LITERATURE CITED

Alaska Energy Authority (AEA). 2012. Revised Study Plan: Susitna-Watana Hydroelectric Project FERC Project No. 14241. December 2012. Prepared for the Federal Energy Regulatory Commission by the Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/study-plan.

de Laguna, F., and C. McClellan. 1981. Ahtna. *In* J. Helm (ed.) Subarctic, p. 641-663. *Handbook of North American Indians* Vol. 6. Smithsonian Institution Press, Washington, DC.

Kari, J. 2008. *Ahtna Place Names Lists*. Revised, 2nd ed. Alaska Native Language Center, Fairbanks.

Kari, J. and J. A. Fall. 2003. *Shem Pete's Alaska. The Territory of the Upper Cook Inlet Dena'ina*. Second edition. University of Alaska Press, Fairbanks.

9. FIGURES

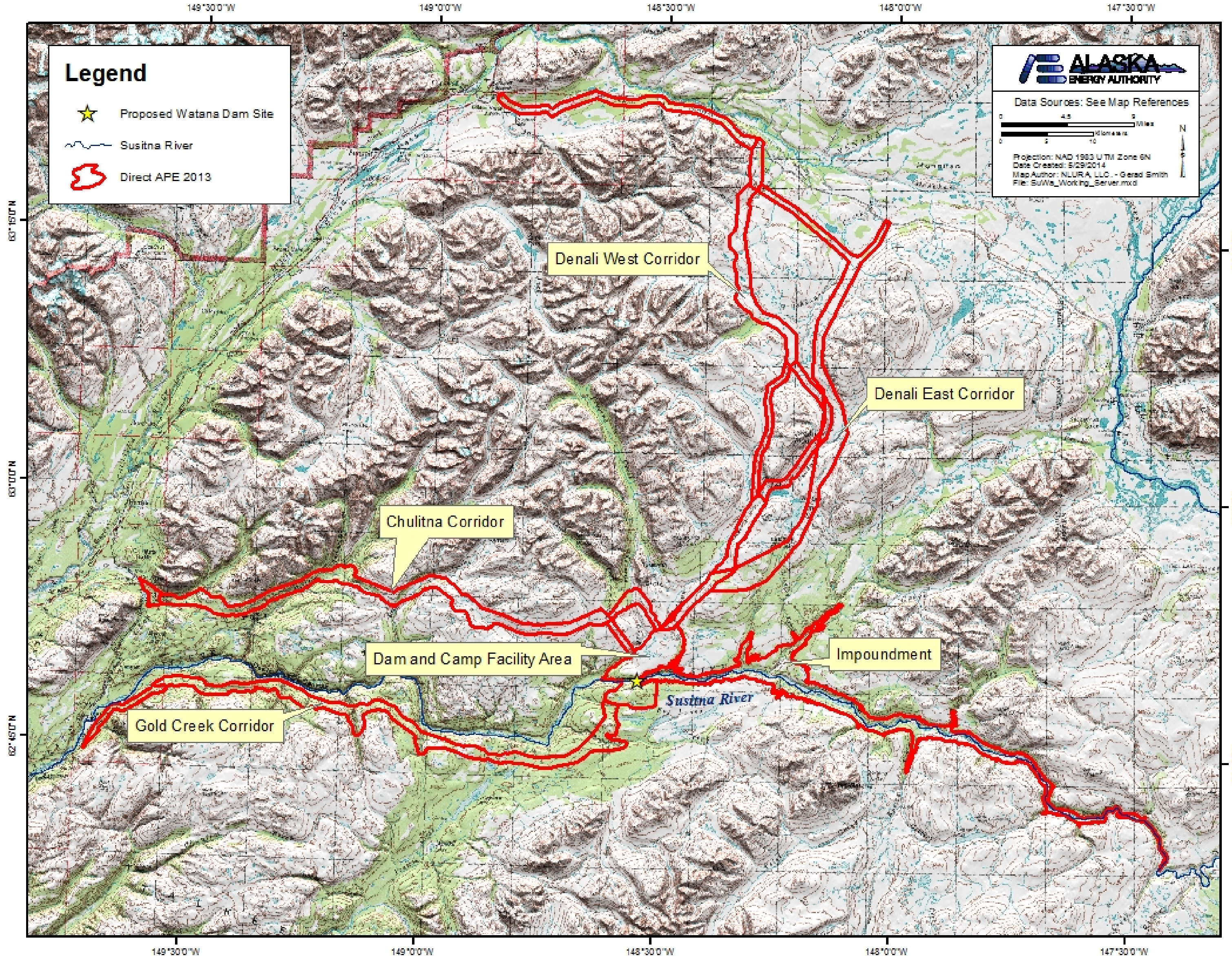

Figure 3-1: Map of the direct APE, including both the Chulitna Corridor and the Denali East Option.

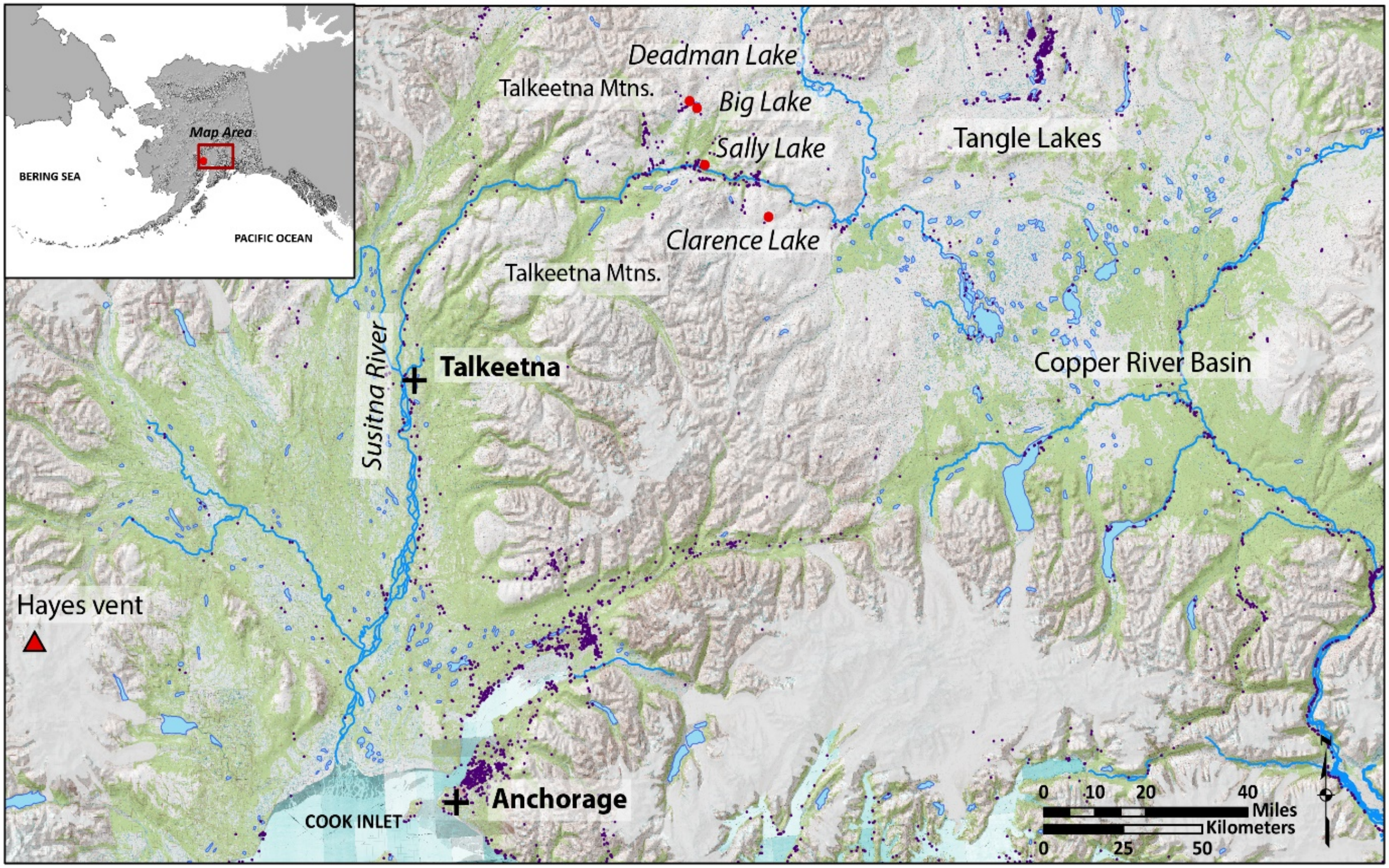

Figure 3-2: Map of the region showing the study lakes, Hayes vent, and archaeological sites from all time periods (purple dots).

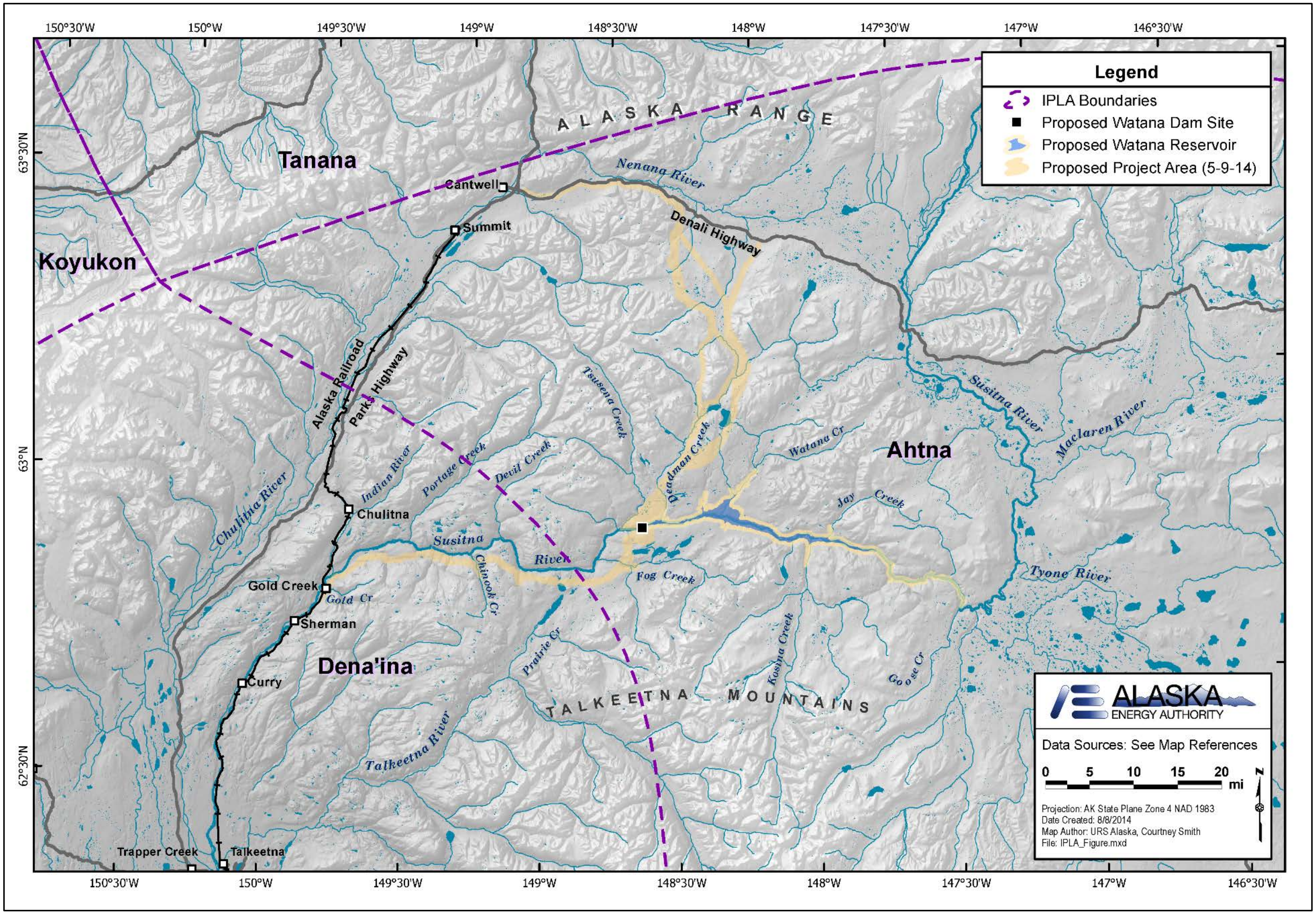

Figure 3-3: Athabascan groups and territorial boundaries in the Study Area.

ATTACHMENT 1: HOLOCENE LANDSCAPE AND PALEOENVIRONMENTS TECHNICAL MEMORANDUM

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Cultural Resources Study
Study Plan Section 13.5

2014-2015 Study Implementation Report

Attachment 1:
Holocene Landscape and Paleoenvironments Technical Memorandum

Prepared for
Alaska Energy Authority

SUSITNA-WATANA HYDRO
Clean, reliable energy for the next 100 years.

Prepared by
University of Alaska Fairbanks
USGS
URS Corporation

May 2016

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
%C	Percent carbon
%N	Percent nitrogen
AEA	Alaska Energy Authority
allochthonous	Within lake
autochthonous	External to the lake
ASIF	Alaska Stable Isotope Facility
atm.	Atmosphere
Al	Aluminum
AT-#	Alaska Tephra Laboratory and Data Center identification number
BP	Before present (by convention, before 1950 CE)
AKDF&G	Alaska Department of Fish and Game
Ca	Calcium
cal	Calibrated
cl	Chlorine
cc	Cubic centimeter
CE	Christian era (= AD)
CIT-ZAF	Matrix corrections software for x-ray analysis
C:N	Carbon to nitrogen ratio
d13C	Stable carbon isotope composition
d15N	Stable nitrogen isotope composition
EPMA	Electron probe microanalysis
FERC	Federal Energy Regulatory Commission
Fe	Iron
GPS	Global positioning system
Gyttja	Organic-rich lake mud

Abbreviation	Definition
HCl	Hydrochloric acid
HF	Hydroflouric acid
HTM	Holocene Thermal Maximum
K	Potassium
KN18	Rhyolite glass standard used for calibration
kV	Kilovolts
KOH	Potassium hydroxide
Lacustrine	Lake (adj.)
LIA	Little Ice Age
Loess	Wind-blown silt
masl	Meters above sea level
MS	Magnetic susceptibility
NLURA	Northern Land Use Research Alaska
nA	Nanoamps
m	Meter
µm	Micrometers
mm	millimeters
MgO	Magnesium oxide
MnO	Manganese oxide
n	Number of data points
Na	Sodium
NAPt	Sodium Polytungstate
NLURA	Northern Land Use Research Alaska, LLC
P	Phosphorous
RO	Reverse osmosis
RSP	Revised study plan
s	Seconds

Abbreviation	Definition
Si	Silica
SiO_2	Silica dioxide
SG	Specific gravity
Tephra	Fine-grained volcanic ash
Ti	Titanium
TN	Total nitrogen
TOC	Total organic carbon
UAF	University of Alaska Fairbanks
URS	URS Alaska, LLC
USGS	U.S. Geological Survey
VPDB	Vienna Pee Dee Belemnite
VG-568	Rhyolite glass standard used for calibration
YDC	Younger Dryas Chronozone
yr, yrs	Year, years

1. INTRODUCTION

In December 2012, the Alaska Energy Authority (AEA) filed a Revised Study Plan (RSP) for the Susitna-Watana Hydroelectric Project with the Federal Energy Regulatory Commission (FERC). This RSP included a study plan for cultural resources that outlined the need to provide information on the paleoenvironment that would help place the archaeological record and in its proper context, and support the cultural resources studies (Section 13.5) within the Susitna-Watana Hydroelectric Project area (AEA 2012). This section provides this necessary background information.

The scope of work and study plan for these paleoenvironmental studies included coring of four lakes within the Susitna-Watana Hydroelectric Project study area to retrieve lake sediments that could be sampled for pollen identification and geochemical analyses. Prior to fieldwork, AEA consulted with representatives from the Alaska Office of History and Archaeology, the Alaska Department of Natural Resources, and the Bureau of Land Management on permissions to access and core lakes.

Fieldwork for this lake coring effort was conducted in April 2014. This report provides the results of the pollen identifications, sediment geochemistry, and dating analyses for the lake coring project, and paleoenvironmental interpretations based on each of these data sets. The information derived from these studies allowed the study to: (1) characterize past environmental conditions over the last 14,000 years; (2) determine the timing of deglaciation in the region; (3) assess the timing of the establishment of lakes in the region; and (4) reconstruct potential past changes in vegetation and lake productivity. The data and paleoenvironmental interpretations derived from these studies will help support future cultural resources studies including constructing and reiterating archaeological site locational or predictive models, assessing changes in human occupation and land use patterns in the region, and building contexts for cultural resources significance evaluations.

2. STUDY OBJECTIVES

The goal of this project is to reconstruct the Holocene landscapes and paleoenvironments of the middle and upper Susitna River, especially as it relates to the humans living there. Human occupation of the region spans the past 10,000 years, although it was most intensively occupied after about 6,000 years ago (Bowers et al., 2012; Dixon et al., 1985). The data and paleoenvironmental interpretations derived from these studies will help support future cultural resources studies including constructing and refining archaeological site locational or predictive models, assessing changes in human occupation and land use patterns in the region, and building contexts for cultural resources significance evaluations.

Lake and bog sediments are suitable for paleoenvironmental studies because they continuously record changes in the surrounding landscape over the lifespan of the deposit, which is typically several thousand to over 10,000 years. Under stable conditions, their surfaces collect airborne sediments that then sink and ultimately settle on the basin floor. By sampling lacustrine (lake) bottom sediments it is possible to characterize past environmental conditions. Lake sediments typically contain pollen grains and other botanical remains, aquatic microorganisms, volcanic ash (tephra), wind-blown silt (known as aeolian silt, or loess), and sand. Through time, the resulting lacustrine beds preserve a record of the area's sedimentation history and vegetation succession.

Four lakes at elevations between 620 and 930 meters above sea level (masl) in the study area were selected for coring. Each of the lakes is situated within a basin that contains numerous archaeological sites and records of prehistoric human land use. Specific analyses conducted include:

- Isotopes (carbon, nitrogen, and oxygen) that provide information on lake productivity, hydrology, and climate.
- Diatoms, which provide information on lake chemistry, water temperature, and water depth.
- Pollen, which provides information on vegetation and climate.
- Chronological analyses (radiocarbon, cesium-137, lead-210, and tephrochronology), so the above results can be placed in a chronological framework.

These analyses enabled the study to reconstruct a history of past changes in lake hydrology, vegetation, and climate of the region. Accurate information on the study area's paleoenvironment allows for the archaeological record to be placed in its proper ecological context, and can contribute temporal depth to analyses of contemporary flora and fauna.

3. STUDY AREA

The project area lies in the middle and upper reaches of the Susitna River where it flows through the lower lying valleys of the Talkeetna Mountains. (Figure 3.-1). The higher peaks of the Talkeetna Mountains can reach up to around 1,800 masl, with the majority of terrain in the valleys between 600 and 900 masl. The more mountainous terrain of the Alaska Range lies to the north and reaches to over 2,000 masl at its highest peaks. The Susitna Glacier feeds the headwaters of the Susitna River at an elevation around 850 masl.

The Susitna River is Alaska's sixth largest river and drains an area over 42,000 km^2 and flows for over 500 km before draining into Cook Inlet. The region's topography has been influenced by tectonics and sculpted by past glaciation and its associated outwash (Dixon et al., 1985; Thorson et al., 1981). The tectonic history and characteristics of the region's bedrock are summarized in Reger et al. (1990) and Smith et al. (1988). The river flows through steep-walled canyons, including the prominent Devil Canyon (Kachadoorian, 1974), in the middle Susitna River region. In this region, broader glacial terrain lies adjacent to these canyons with terrace scarps created by drainage down-cutting. Glacial features are present throughout much of the study area including moraines, eskers, kames, and kettle lakes (Dixon et al., 1985; Kachadoorian, 1974; Reger et al., 1990). Large proglacial lakes, which created glaciolacustrine plains, once covered vast portions of the study area including the upper reaches of Deadman and Brushkana Creeks (Reger et al., 1990).

The most recent geological history of the middle and upper Susitna (over the last 15,000 years), is more pertinent to the human history of the region and these paleoenvironmental studies. Much of the study area was heavily glaciated during the Late-Wisconsinan (ca. 25,000-14,000 cal yr BP), with ice originating from the Alaska Range to the north and the Talkeetna Mountains to the south and northwest. The regions around Dead Man, Big, and Sally lakes were covered by thick ice until deglaciation; the basal radiocarbon dates at all three lakes suggest deglaciation was before 11,000 cal yr BP, possibly as early as 14,000 cal yr BP. In contrast, the region around Clarence Lake was apparently ice-free during the Late-Wisconsinan (Woodward-Clyde Consultants, 1982). After deglaciation, Holocene-aged ice was limited to cirques with little growth into the valleys and the study lakes would have only been indirectly (if at all) affected by these ice advances (Reger et al., 1990; Woodward-Clyde Consultants, 1982).

The climate of interior Alaska was much cooler and more arid during the last glaciation than at present. By the Late Glacial period (16,600 to 12,900 cal yr BP), the climate began to trend toward warmer climates and increased humidity. The vegetation of interior Alaska has undergone dramatic changes over the past 16,000 cal yr BP (see Bigelow, 2013 and references therein). During the waning phases of the last glaciation, the vegetation was a sparse herbaceous tundra with wide areas of disturbed soils. By about 14,500 cal yr BP, willows become more common, but the vegetation was still dominantly herb-rich. Abruptly, about 14,000 cal yr BP, birch shrubs dominate the landscape. Herbaceous plants, such as grasses, sedges, and *Artemisia* (sage or wormwood) were still common, but the overall productivity increased, so that there was much less unvegetated ground than previously. This birch shrub tundra dominated the landscape for several millennia, although some records suggest a reduction in shrubs and increase in non-woody plants during the Younger Dryas Chronozone (YDC, ca. 12,900 to 11,700 cal yrs BP).

The YDC represents a time at the end of the Late Glacial period when several areas around the world experienced an abrupt shift toward cooler average temperatures that lasted for just over a millennium.

The end of the YDC and the shift again toward warmer temperatures marks the beginning of the Holocene around 11,700 cal yr BP. The Holocene is separated into three sub-periods: the early Holocene (11,700 to 7,000 cal yr BP), middle Holocene (7,000 to 3,000 cal yr BP), and late Holocene (3,000 cal yr BP to present). The general climatic trend of the Holocene is toward warmer temperatures and increased moisture. Between 11,000 and 8,000 cal yr BP, a period often referred to as the Holocene Thermal Maximum (HTM), many northern environments experienced higher average summers temperatures than at present. Starting about 11,000 cal yr BP, many records indicate the expansion of *Populus* (cottonwood or aspen) across the Interior as well as north of the Brooks Range. This is the first evidence of trees since the last ice age. The vegetation, a deciduous broadleaf forest, is different from anything seen today in Alaska and its presence is probably related to warmer than modern summers during the HTM.

Several minor glacial readvances occurred after 6,000 cal yr BP and the Neoglacial period has been suggested to encompass all of the glacial advances between 6,000 cal yr BP into the early historic period (Porter 2007). This definition includes the Little Ice Age (LIA; ~1100 to 1880 A.D.) as its youngest glacial advance (Barclay et al., 2009). Vegetation shifts during the middle and late Holocene are subtle. Essentially, spruce and alder expand in the lowlands before about 8,000 cal yr BP and a vegetation very similar to today’s boreal forest is in place by about 6,000 cal yr BP.

Human Occupation. Currently, the oldest well-documented archaeological remains, dating to around 14,000 cal yr BP, in Alaska are from the Swan Point site in the middle Tanana Valley, approximately 350 km north of the project area (Holmes, 2011). In the northern portions of the Alaska Range foothills, archaeological sites date back to 13,000 cal yr BP (Hoffecker, 2001). In the southern and western portions of Alaska Range, several sites date between 12,000 and 10,000 cal yr BP (Blong, 2011; Bowers and Reuther, 2008; Coffman and Potter, 2011; Graf and Bigelow, 2011; Holmes et al., 2010; Wygal, 2010; Wygal and Goebel, 2012). Over this period, artifact assemblages, in particular stone tools, display a wide variation in morphology, the ways they are manufactured, and their perceived uses. The causes of this variation are widely debated among archaeologists and have been primarily attributed to stylistic and technological dissimilarities among cultural entities, and differences in the use of tools and technologies within one cultural tradition seasonally and for procuring different subsistence resources (see chapters in Goebel and Buvit, 2011). Late Pleistocene and early Holocene cultural traditions and complexes in interior Alaska generally include the Nenana (or Chindadn) Complex, the Denali Complex of the American Paleoarctic tradition, and the Northern Paleoindian tradition. Bowers et al. (2012) summarizes the prehistoric cultural traditions and complexes for the region.

In the study area, the earliest documented human occupation is the lowest component at Jay Creek Ridge that dates ca. 10,700-10,900 cal yrs BP (Bowers et al., 2012; Dixon, 1999). The Tangle Lakes and upper Maclaren River regions, to north and northeast of the project area, also have occupations that date to 12,000 to 10,000 cal yrs BP (Blong, 2011; Wygal and Goebel, 2012). Most researchers associated these occupations to the Denali complex of the American Paleoarctic tradition (Dixon, 1985; Wygal and Goebel, 2012; Vanderhoek, 2011); however, the Jay Creek Ridge site assemblage also has been related to a Northern Paleoindian tradition by Dixon (1999).

The late Pleistocene and early Holocene human occupations in interior Alaska appear to have focused on a broad spectrum of subsistence resources, but still maintained a high reliance on large terrestrial mammals (Graf and Bigelow, 2011; Potter, 2008a; Potter et al., 2013; Yesner, 1996, 2007). Bison and wapiti (extinct elk) represent a large portion of the larger mammals hunted during this period, likely being acquired in more lower-lying valleys (Potter, 2008a, 2011; Yesner, 2007). Caribou and sheep remains are also found in lesser extent in sites dating to this time period (Bowers, 1980; Potter, 2011; Powers et al., 1983; Yesner et al., 2011). Mason et al. (2001) hypothesized a relationship of increased numbers of dated components around 8,000 cal yrs BP to a colder, more arid climatic period and the expansion of caribou populations.

Waterfowl are highly represented in the earliest part of the faunal record and prior to and during the Younger Dryas, but lessen in their presence in the early Holocene record (Graf and Bigelow, 2011; Potter et al., 2013; Yesner, 2007). Fish species (Salmonids) begin to show up in low quantities the faunal record between 12,600 and 11,000 cal yrs BP (Potter et al., 2011; Yesner, 1996).

Several researchers suggest a 2,000 to 3,000 year hiatus or population decline in interior Alaska beginning around 8,000 to 7,000 cal yrs BP (Holmes, 2008; Potter, 2008a). While there appears to be fewer dated components around this time frame, there does not seem to be a hiatus in the strictest sense of the word (Potter, 2008b). Potter (2008a) notes that this decline in dated component abundance is consistent with hypothesized scenarios of population replacement and/or shifts in subsistence strategies and population sizes within existing populations. Component abundance appears to steadily increase in the middle Holocene after 6,000 cal. yrs BP (Potter, 2008a).

Middle Holocene (7,000 to 3,000 cal yrs BP) components in interior Alaska yield lithic assemblages that display new projectile point forms (i.e., notched points), while maintaining several technologies from the early Holocene complexes or traditions. This change in projectile point forms generally signifies a transition into what is termed the “Northern Archaic tradition” (Anderson, 2008; Dixon, 1985; Esdale, 2008). Other characteristics attributed to the Northern Archaic assemblages are the relatively high frequency of scrapers and the presence of notched stones that may indicate their use as weights on nets for fishing (Anderson, 2008; Esdale, 2008). Microblade and microcore technology continued to be used throughout this period (Dixon, 1985; Holmes, 2008; Potter, 2008b).

Middle Holocene subsistence patterns likely remained similar to those that developed in the early Holocene, with the exception of caribou and moose becoming more and more prevalent (Potter, 2008a). The staple subsistence resource in many Northern Archaic faunal assemblages is caribou (Esdale, 2008; Potter, 2008a). In addition, many of the regions in which Northern Archaic lithic assemblages are found likely supported caribou populations during the middle Holocene.

Bison and sheep occur in lower numbers in middle Holocene assemblages, and wapiti drops out of the record (Potter, 2008a, 2008b). The causes of the local extinctions of wapiti in the Holocene remain unclear. Bison populations inhabited the lowlands in interior Alaska into the late Holocene (Stephenson et al. 2001). The decline of bison populations and local extinctions in interior Alaska may be the result of climate and habitat change coupled with over-hunting with the introduction of bow and arrow technology around 1,500 to 1,300 cal yrs BP (Potter, 2008a, 2008b).

Northern Archaic components are relatively abundant in the region, when compared to early Holocene components (Dixon, 1985; Dixon et al., 1985; Esdale, 2008; Potter, 2008b). In the study area, Northern Archaic components date back to around 6,000 cal yr BP (Dixon, 1985). Caribou remains are highly represented in faunal assemblages in Northern Archaic components (Dixon et al., 1985). Northern Archaic components in the region appear to decline or disappear around 1500 cal yr BP (Dixon, 1985; Dixon et al., 1985).

The Athabascan tradition in interior Alaska encompasses components that span around the last 1,500 to 1,000 cal yrs BP. Major changes in technology and subsistence and settlement strategies in interior Alaska occurred around 1,300 to 1,000 cal yrs ago (Cook, 1975; Dixon, 1985; Potter, 2008a; Workman, 1978). The bow and arrow became more prominent as dart point usage decreased (Hare et al. 2004, 2012), most likely with a concomitant reduction in projectile point size (Holmes, 2008; Potter, 2008a). Microblade use dramatically declines in the late Holocene with only a few microblade components dated to this period (Potter, 2008a). Organic tool and metal use becomes increasingly prominent in the technological strategies in the late Holocene (Cook, 1975; Dixon, 1985; Holmes, 2008). The use of local copper ore from the Copper River region becomes widespread, and is traded into adjacent regions including the Nenana and Susitna River Valleys (Cook, 1975; Dixon et al., 1985; Plaskett, 1977; Workman, 1977).

The technology, settlement patterns, use of subsurface storage features, and subsistence strategies of this tradition reflect those described in the ethnographic literature on interior Athabascan cultures. Thus, there appears to be a direct historical link between interior Athabascan cultures and archaeological components in the interior Alaska dating back at least to 1,000 cal yrs BP, if not to older periods in the middle Holocene (Anderson, 1988; Cook, 1975; Dixon, 1985).

Lowland and upland resource use appears to have not significantly changed from the middle Holocene. Caribou was the dominant large mammal resource in the Athabascan tradition in interior Alaska (Potter, 2008b; Yesner, 1989). However, moose became more important to Athabascan subsistence in early historic times (Yesner, 1989). The dietary spectrum remained relatively broad; birds, small mammals and carnivores continued to be an important part of the subsistence system into historic times (Potter, 2008b; Shinkwin et al., 1980; Yesner, 1989). Fishing likely became more prevalent during the later stages of the Holocene, possibly as bison populations began to diminish (Potter, 2008a).

3.1. Site Descriptions

3.1.1. Clarence Lake

Clarence Lake (N62.6784; W147.8108 [Table 3.1-1]) is located south of the Susitna River at about 870 masl, approximately 120 km east northeast of Talkeetna (Figures 3.-1 and 3.1.1-1). The lake is about 3.2 km long and 0.5 km at its widest point, with the long axis oriented northeast-southwest (Figure 3.1.1-2). The lake is situated near the center and lowest point of a basin with the surrounding hills rising up to 100 m above the lake's margins. Based on an AKDF&G bathymetric map, the maximum lake depth is about 35 feet (ca. 11 m) (Figure 3.1.1-2). An outlet at the western end of the lake drains into Gilbert Creek that drains into Kosina Creek and, ultimately, into the Susitna River. The lake has three major inlets at its western and northern margins. The vegetation around the lake is shrub tundra with widely scattered spruce trees (Figure 3.1.1-3). Fish species identified in Clarence Lake include arctic grayling, lake trout and whitefish (HDR, 2013).

3.1.2. Deadman and Big Lakes

Deadman Lake (N63.0059; W148.2650 [Table 3.1-1). and Big Lake (N62.9979; W148.2051 [Table 3.1-1]) are paired lakes north of the Susitna River approximately 120 km north east of Talkeetna (Figures 3.-1 and 3.1.1-1). The lakes are situated in a basin shaped by late Pleistocene glaciations. The surrounding landscape consists of higher elevation peaks that reach up to 1,500 masl and nearly 600 m above the lake margins, such as Deadman Mountain at the northern end of Deadman Lake and peaks to east of Big Lake. The lakes are 934 and 936 masl respectively.

Deadman Lake is ca. 2 km long and 1 km wide with its long axis oriented roughly east-west (Figure 3.1.2-1). The AKDF&G bathymetric map indicates the maximum depth in 1983 was about 92 feet (ca. 28 m).

Big Lake is ca. 3 km long and 1.3 km wide, with a large, shallow (1-2 m) embayment at its northwest corner. Spot water depth measurements indicate the basin is at least 29 m deep (Figure 3.1.2-2).

At some point in the past, Big Lake likely drained into Deadman Lake, although today each lake has its own outlet. The two lakes were likely once part of a larger proglacial lake system in the area (Reger et al., 1990). Deadman Creek for serves both as an inlet at the eastern margin and as an outlet at the western margin of Deadman Lake. Watana Creek serves as an outlet for Big Lake at its southern end. Inlets into Big Lake are relatively minor, draining seasonal meltwater from the surrounding hills into its basin.

The vegetation around the lakes is tundra with low and high shrubs (the tallest shrubs are around the lakes and in the gullies). A few spruce trees were noted on the slopes to the northeast of Big Lake (Figures 3.1.2-3 and -4). Fish species identified in Deadman Lake include arctic grayling, burbot, dolly varden, lake trout, sculpin and whitefish (HDR, 2013).

3.1.3. Sally Lake

Sally Lake (N62.8356; W148.1878 [Table 3.-1]) is located just north of the Susitna River, approximately 113 km northeast of Talkeetna (Figures 3.-1 and 3.1.1-1 regional and local maps) and the lake elevation is about 620 masl. The lake is likely a kettle lake that formed on a glaciofluvial plain that has been downcut by the Susitna River to create a terrace scarp, less than a km south of the lake (Dixon et al., 1985; Reger et al., 1990; Woodward-Clyde Consultants, 1982). Several other smaller kettle ponds surround the lake. The hills surrounding Sally Lake rise up to 35 m above the lake margins, and are somewhat lower in elevation than those surrounding the others lake in this study.

The lake is about 1 km long and consists of two lake basins and the lake width varies between 250 m and 100 m. Water depth was measured only in the northern basin, where it was about 7.6 m (Figure 3.1.3-1). An outlet at the northwestern margin of Sally Lake drains into Watana Creek. Boreal forest surrounds the lake, though the spruce trees are more widely scattered than in lower elevations (Figure 3.1.3-2). Fish species that have been identified in Sally Lake include arctic grayling, sculpin and lake trout (HDR, 2013).

4. METHODS AND VARIANCES IN 2014

4.1. Field Methods

Between April 13th and 17th, 2014 field research was conducted at four lakes in the middle and upper Susitna valley. The analyzed lakes are Deadman, Big, Clarence, and Sally Lakes (Figure 3.1.1-1). All four lakes were accessed by fixed wing aircraft on wheel-skis. Upon landing on the lake, the plane taxied as close as possible to the coring location (Figure 4.1-1) that were identified using lake bathymetry maps (Figures 3.1.2-1 and 3.1.2-2). Coring locations were chosen based on distance from steep slopes above the lake (to reduce the likelihood of debris flows at the coring site), the presence of a relatively flat lake bottom, and a water depth less than about 20 m. Wherever possible, the decision was made to core in 15 m of water or less, as this was the optimal depth for our coring equipment. Upon reaching the coring location, holes were drilled in the ice with a power ice auger (Figure 4.1-2). Water depth was measured with a weighted 30 m tape and commenced coring. All coring and water depth measurement sites were located with a GPS (Table 3.1-1). The sediment-water interface was collected with a $2^{3/4}$ inch diameter core and preserved in the core by adding a super absorbent polymer which gelled the overlying water and stabilized the sediments (Figure 4.1-3). Underlying sediments were collected by a modified square-rod

Livingstone corer with a 2” diameter steel barrel that is 1 m long (Wright et al., 1984). Thus each core is made up of multiple drives. As each drive was collected from the lake bottom, it was extruded into a split ABS pipe lined with plastic film liner, wrapped, labelled, and packaged for transport.

The surrounding vegetation and ice thickness was noted at each coring locality. In addition, for lakes that did not already have a bathymetry (Big and Sally Lakes), the water depth at several locations was measured to assist in choosing a good coring site.

4.1.1. Variances

No variances from the field methods were necessary in 2014.

4.2. Dating the Cores and Building Chronologies

The lake cores were dated with radioisotope analyses (^{14}C [radiocarbon], ^{210}Pb, ^{137}Cs). Samples for radiocarbon analysis (plant macrofossils) were sieved and cleaned with reverse osmosis (RO) water prior to submission to the radiocarbon laboratory (Center for Applied Isotope Studies, University of Georgia). In addition to plant macrofossils, pollen extracts (primarily spruce pollen) was radiocarbon dated. The pollen extracts were processed using a combination of acid and base washes as well as sieving (125, 90 and 20 micron sieves) (c.f. Brown et al., 1989) and heavy liquids. The water-based heavy liquid (Sodium Polytungstate [NaPt]) was used initially at SG 2.0 to remove silicates (Brown et al., 1989), and then in sequentially lighter densities (starting at SG 1.6 and ending at SG 1.25) to remove additional non-pollen material (Vandergoes and Prior, 2003). The resulting preparations were dominantly pollen, though other material (i.e. plant fragments and occasional insect bit) was also present.

All radiocarbon dates were calibrated using the IntCal13 calibration dataset (Reimer et al., 2013). For the purposes of building chronologies (see below), the calibrated median probability age of the radiocarbon date was used. When comparing archaeological and environmental chronologies, the calibrated range of two standard deviations was used.

Lead-210 (^{210}Pb) and cesium-137 (^{137}Cs) age models were used to calculate the recent sediment accumulation rate in the lakes. The use of radiocarbon dating over the last 100-200 years is imprecise due to human-induced carbon fluctuations in the atmosphere through burning fossil fuels and nuclear testing. The content of ^{210}Pb and ^{137}Cs at the top of cores was used over this more recent period to better understand the recent history. Once a reliable sediment accumulation rate for a lake is understood, and coupled with radiocarbon dating, ^{210}Pb and ^{137}Cs dating was used to provide a more precise age model for the youngest lake sediments. Sediment samples from the top ca. 10 cm of the Deadman Lake core were submitted for analyses to Flett Research Ltd, who is measuring and calculating ^{210}Pb and ^{37}Cs age models.

At three lakes (Big, Deadman, and Sally), the resulting ages were suitable for building a chronology of lake sedimentation. Chronologies were built by plotting the age/depth relationship of the accepted dates and, by a variety of means, calculate the sediment ages between them. At Deadman and Sally Lakes, the dates follow a consistent age/depth relationship (i.e., no reversals) and thus the sediment ages were calculated by linear interpolation between the dates. At Big Lake, because of minor reversals at about 40-50 cm depth, a linear fit ($R^2 = 0.9157$) was used for those dates though other dates (both older and younger) were consistent (no age reversals), and data had to be interpolated between those dates. A chronology for Clarence Lake was not built because the dates are clustered in specific levels with numerous age reversals. See Section 5.2 below for more information on dating the cores and the resulting chronologies.

4.2.1. Variances

The only variance from the dating methods was that ^{210}Pb and ^{37}Cs age models were only conducted on a single lake core, Deadman Lake. The primary factor for this decision was that the top 20 cm of sediment from the other lake cores were disturbed, which would have made ^{210}Pb and ^{37}Cs calculations difficult and less precise.

4.3. Tephra

Tephras or presumed tephras were identified visually and texturally in split core surfaces. Individual tephras were sampled from one side of the split core, reserving the other half for archive. Single samples were collected for layers 1 cm thick or less and multiple samples were collected for thicker layers (>1 cm) to test for compositional zonation. All tephra samples were processed at the U.S. Geological Survey (USGS) Alaska Tephra Laboratory & Data Center in Anchorage, Alaska.

Splits of the bulk samples were wet sieved using tap water into three size fractions (0.063, 0.125, and 0.250 mm) to remove very fine-grained ash and allow for microscopic analysis. The 0.250 to 0.125 mm size fraction was preferably mounted for electron microprobe microanalysis (EPMA) or the 0.125 to 0.063 mm material was used for finer-grained samples. All samples finer than 0.063 mm could not be analyzed using the electron microprobe and therefore, there are no geochemical analyses for those samples. Splits of all tephra samples are archived at the USGS Alaska Tephra Laboratory in Anchorage, AK.

Basic visual descriptions of the tephras were done using either a binocular or a petrographic microscope at 100X and 500X magnification.

Major-element glass analyses were con-ducted using wavelength dispersive techniques with a 5-spectrometer JEOL JXA-8530F field emission electron probe microanalyzer (EPMA) at the Advanced Instrumentation Laboratory at the University of Alaska, Fairbanks. Probe for EPMA software was used for automation. Concentrations were determined with the CIT-ZAF reduction scheme (Armstrong, 1995). Glass analyses used a 5-µm-diameter beam with 5 nA current and 15 kV accelerating potential. Count times were 20 s for Na (which was analyzed first to reduce Na-loss), 10 s for Cl, P, and K and 20 s for all other elements. Mineral standards were used for calibration: Wollastonite for Si and Ca; Hematite for Fe, MgO for Mg; Orthoclase 1 for K and Al; Tiburon albite for Na; Willimite for Mn; Ilmenite for Ti; scapolite for Cl; and Wilberforce apatite for P. Standard deviations of averages of multiple spot analyses for single unknown samples are generally within those listed above for working standards. Water-by-difference was included in the X-ray matrix corrections for the tephra samples to provide improved results on secondarily hydrated glasses. During analysis, sets of 5 replicate analyses of secondary glass standards KN18, VG-568, rhyolite glass, and (Jarosewich et al., 1979) were performed to monitor instrument drift.

Reported glass compositions are the averages of 10–25 spot analyses or fewer if multiple populations were found within a single sample; background intensities were determined 1–3 times for each grain.

4.3.1. Variances

No variances from the methods were necessary.

4.4. Magnetic Susceptibility and Loss-on-Ignition

Magnetic susceptibility (MS--a measure of the quantity of magnetic grains) was measured using a Bartington MS ring on whole cores at 1, 2, or 5 cm interval. The resolution was sufficient to document the cm-thick tephras, but it is too coarse for the mm-scale tephras.

4.4.1. Variance

The original plan was for high-resolution (1 cm interval) MS analyses; instead, the study conducted the measurements at a coarser interval as this was sufficient for correlating the cores. The original intent was to perform loss-on ignition (LOI) analyses. No LOI analyses, (an indirect measure of %C), were made on the cores. This is because direct measurements of %C (described below), was at a sufficient sample resolution to make LOI unnecessary.

4.5. Isotopes and Diatoms

Isotope samples (~1cc) were collected at four or five cm intervals from along the length of the cores taken from all four lakes (Clarence, Big, Deadman, and Sally). Samples from the cores were examined for the resources to be able to measure stable oxygen isotope analyses (biogenic carbonate, diatoms, and chironomid headcapsules). Each sample was then acid fumed with HCl to remove any trace amounts of carbonate. Samples were then freeze dried and weighed for analysis using an isotope ratio mass spectrometer at the Alaska Stable Isotope Facility (ASIF) on the UAF campus. The analyses of each sample produced a stable carbon isotope values ($\delta^{13}C$), which is expressed relative to an international standard (VPDB). The analyses also produced a stable nitrogen isotope value ($\delta^{15}N$), which is expressed relative to atmospheric nitrogen (atm.). A total organic carbon (TOC) %C value, total nitrogen (TN) %N value and C:N value were also produced from the analysis of each sample.

For the diatoms, a measured amount of wet sediment (between 0.11 and 0.15 g) was treated for 25 samples distributed throughout the Clarence Lake core. Diatom preparation followed standard procedures outlined in Battarbee et al. (2001). A minimum of 400 diatom valves was enumerated for each sample using a Leica DM microscope (100 x magnification under oil immersion). Identification followed mainly Canadian floras, including Antoinades et al., Cumming et al. and Fallu et al. 2000. A diatom-based inference model developed from a set of Alaskan lakes (Gregory-Eaves et al. 1999) was applied to the sedimentary data in order to reconstruct past variations in lake depth, conductivity and total phosphorous (TP). The model was implemented and results plotted using the software C2 (Juggins 2014).

4.5.1. Variances

The cores were to be examined to see if there were materials available for $\delta^{18}O$ analyses. In no case were sufficient biogenic carbonate, such as fingernail clams, observed. Biogenic carbonate remains are usually the most cost efficient means of generating oxygen isotope data. Chironomid and diatom remains were observed in all of the organic rich lacustrine samples from the cores and these can potentially be used to generate oxygen isotope data from lake cores. However, this method is exceedingly labor intensive and time consuming and was beyond the scope of work. However, prompted by the carbon isotope results and subsequent interpretation of the data, analyses of diatoms that were well preserved in the core were added. Some of the interpretations of the stable isotopic data implied that lake levels had changed significantly at Clarence Lake (and the other lake sites). So, to test this interpretation at at least one site, diatom species composition changes were analyzed. Twenty-five samples were selected from along the Clarence Lake core to send to Dr. Emilie Saulnier-Talbot, who is an expert in high latitude diatom identifications and analyses.

4.6. Palynology

Three lakes were analyzed for pollen, Clarence Lake (core 14CL-2), Deadman Lake (core 14DL-1), and Sally Lake (core 14SL-3). Volumetric samples (1 or 2 cc) were collected at a four or five cm interval, though in general, only an eight or ten cm interval was actually analyzed for pollen. The pollen samples were processed using standard techniques described in Faegri and Iversen (1989). Briefly, this includes first adding a known volume of exotic pollen (as tablets), then acid (10% HCl) and base (10% KOH) washes followed by hydroflouric acid (HF) to remove silicates, and acetolysis to clear the grains. The samples were then dehydrated in tert-butyl alcohol and suspended in silicone oil and mounted on slides. With very silty samples (typically at the bottom of the cores), the samples were floated in NaPt at 2.0 SG after the base wash and the suspended pollen poured onto a fiber glass filter which was then dissolved in HF. The remaining processing followed standard techniques of Faegri and Iversen, 1989.

Prepared pollen slides were then counted on a transmitted-light Nikon Optiphot microscope at 400X and 1,000X. The pollen identifications were made by comparison with the pollen reference collection housed at the Alaska Quaternary Center and the Department of Geosciences at UAF, as well as comparison with published pollen atlases such as Moore et al., 1991; Moriya, 1976, and McAndrews et al., 1973. As the pollen grains were counted, the exotic pollen (*Lycopodium clavatum*) was also tallied. Pollen counting stopped when a sum of at least 150 terrestrial pollen grains was reached, with the exception of a single very silty sample, where the sum was about 100 terrestrial pollen grains. These pollen counts were then calculated as percentage, concentration (grains/cm^3), and influx values (grains/cm^2/yr). The pollen percentages are based on a variety of pollen sums. The percentages of trees and shrubs are based on the total for those taxa (this is the basic pollen sum). The percent of spore-producing plants is based on the basic pollen sum plus the spore-producers. The percent of aquatic plants is based on the basic pollen sum plus the aquatics, and the percent of *Pediastrum* (an aquatic alga) is based on the basic pollen sum plus the *Pediastrum*.

4.6.1. Variances

Pollen counts were conducted primarily on Clarence and Deadman Lakes. At Sally Lake, only the samples that contain spruce (*Picea*) were counted (younger than about 7,000 cal yr BP) because the goal was to see how the history of spruce varied among the three lakes. Pollen analysis was not conducted on Big Lake because it is adjacent to Deadman Lake and therefore the pollen results would have been identical.

5. RESULTS

5.1. Chronology and Sediment Stratigraphy

Sediment cores from Clarence, Deadman, Big, and Sally lakes are summarized below and presented graphically in figures. All depths (both for the radiocarbon dates and for the cores themselves) are measured relative to the bottom of the lake (the sediment-water interface). Table 5.1-1 summarizes the drive depths in each core. Tephra samples are listed here as part of the overall lake-core stratigraphy but more detailed results including all tables and figures for tephras are given in Section 5.2.

5.1.1. Clarence Lake

Two cores were collected from Clarence Lake (14CL-1 and 14CL-2), though most of the analyses were conducted only on 14CL-2. Tephras were analyzed from both cores.

A suite of nine radiocarbon dates were analyzed from core 14CL-2 which roughly span roughly the past 11,000 years (Table 5.1.1-1, Figure 5.1.1-1). The radiocarbon dates contain age reversals which are difficult to interpret. The date at 309-313 cm (10,593 cal yr BP [calibrated yr BP]) is younger than the adjacent dates and presumably represents younger material contaminating the core. The dates at 272-279 cm (10,726 and 11,446 cal yrs BP) as well as at 318 cm (11,341 cal yr BP) are difficult to interpret because it is unclear which dates are the more reliable. Likewise the date at 162-166 cm (5,516 cal yr BP) is nearly 1,000 yrs younger than a date 35 cm higher in the core. The upper four dates (spanning 102-128 cm) are somewhat internally consistent, ranging between about 4,000 and 6,500 cal yrs BP. Due to these dating inconsistencies, an age model was not constructed for this core. However, rough age estimates based on these dates are used when discussing this core.

14CL-2 is about 3.6 m long, with a basal age older than about 11,300 cal yr BP (Figure 5.1.1-1). The basal 50 cm of sediment is silt and sand, reflecting an ephemeral and shallow lake at this time. Above this (starting at about 320 cm, roughly 11,400 cal yr BP) and continuing to the core top, gyttja (organic-rich lake mud) dominates. Zones of mm-scale laminae occur at 320-260 cm (ca. 11,500-10,000 cal yrs BP) and 178-110 cm (ca. 5,000-4,000 cal yrs BP). Silt bands are scattered throughout the core, though they dominate in the basal half (below about 200 cm).

Six definite tephras are preserved in 14CL-2 core and range from 0.05 to 4 cm thick and are located at 330.5 cm, 289 cm, 226.5 cm, 224.5 cm, 94 cm, and 49 cm below the sediment-water interface. An additional four very fine grained, 1-mm thick bands are also preserved in this core and are presumed to be tephras. These are located at 238 cm, 226.5 cm, 224.5 cm, and 211.5 cm below the sediment/water interface. In 14CL-1, there are five definite tephras as continuous bands and range from 0.1 to 4 cm thick and are located at 213.5 cm, 191 cm, 163 cm, 103 cm, and 64 cm. An additional five very fine grained, 1-3 mm thick bands are also preserved and are presumed to be tephras. These are located at 322 cm, 242 cm, 214 cm, 213 cm, and 133 cm below the sediment-water interface. All tephras and presumed tephras from 14CL-1 core are labelled on 14CL-2 core shown in Figure 5.1.1-1.

The MS data from 14CL-2 (Figure 5.1.1-2) mark the major tephra units at about 100 cm and 330 cm, but the thin, mm-scale tephras were not measured because the analytical resolution is too coarse. Despite this, the data do indicate areas with low mineral influx (when the MS is near zero), such as ca. 300-200 cm. MS increases higher in the core, with the core top having MS values that are only slightly less than the silt and clay at the base. The MS data for core 14CL-1 is very similar to 14CL-2 confirming that the cores are virtually identical and correlating the sediments between them is possible.

5.1.2. Deadman and Big Lakes

Deadman Lake core 14DL-1 was analyzed for this project. A suite of eight internally consistent radiocarbon dates (Table 5.1.1-1) were found and the resulting age model is a linear interpolation between those dates with the core top set to 0 yr (Figure 5.1.2-1). The overall sedimentation rate is 2.0 cm/100 yr. The basal radiocarbon date (10,466 cal yr BP) is about 30 cm above the core base. If the sedimentation rate is unchanged in the lowest part of the core, then the extrapolated age of the lowest lake sediments is about 14,000 cal yr BP (Figure 5.1.2-2).

To generate an age model for the youngest sediments, 20 samples in continuous 0.5 cm-thick slices between 0 cm and 10 cm from 14DL-1 were analyzed for ^{210}Pb and ^{137}Cs (Table 5.1.2-1). ^{210}Pb reached background levels at about 5.5 cm depth and the resulting age models indicate an age of about 100 years at 4-4.5 cm depth (Figure 5.1.2-1).

The basal ca. 10 cm of the core are gray silt, sand, granules and probably represent the lake basin prior to filling. Above this is about 20 cm of gray and tan silt, to about 210 cm. The presence of *Pediastrum* nets indicate the basin was perennially filled (if shallow) at this time. The remainder of the core is gyttja with bands of laminae, fine silt, and tephra. Lenses of fine silt are present after about 4,000 cal yr BP and represent episodes of shoreline instability. Five tephras are preserved in 14DL-1 core and range from 0.05 to 4-cm thick. Tephras are located at about 1 cm, 115 cm, 142 cm, 153 cm, and near the base, at 237 cm. Their approximate ages are ca. 0, 2,500, 4,300, 4,900 cal yr BP and somewhat older than 10,000 cal yr BP. The MS data marks the tephras at ca. 145 cm, 116 cm, and at the core top (Figure 5.1.2-3). Otherwise, MS values are low, except at the core base where there is increasing silt, and in the basal 5 cm, sand.

Big Lake (Core 14BL-A) has a suite of 11 radiocarbon dates (Table 5.1.1-1) and the age model is a combination of interpolation between some dates and a linear fit of other dates due to small age reversals (Figure 5.1.2-4). The overall sedimentation rate is about 1.4 cm/100yr, which is about 70% of Deadman Lake's rate. The basal ca. 50 cm (ca. 200-250 cm; older than ca. 11,500 cal yr BP) is dominated by gray silt and clay with sand bodies at the base of the core (Figure 5.1.2-5). Laminated silty gyttja (indicating a perennial lake) dominates much of the remainder of the core with occasional zones of massive gyttja. The gyttja is increasingly organic-rich in the upper 50 cm (younger than ca. 2500 cal yr BP), where the laminations also become less frequent. Four tephra layers were recognized in the core and range from 0.1 to 4-cm thick. Tephras are located at 96 cm, 81 cm, 49 cm and 40 cm sediment-water interface with approximate ages of about 6,400, 5,000, 2,500, and 1,900 cal yr BP, respectively (Figure 5.1.2-5). The MS data also marks the thicker tephras at ca. 98 cm, 80 cm, and 50 cm (Figure 5.1.2-3). Aside from the tephras, the MS values are highest in the sand and silt at the core base. The lowest values are in the gyttja and near the core top.

5.1.3. Sally Lake

Sally Lake (core 14SL-3) has a suite of three radiocarbon dates that are internally consistent (Table 5.1.1-1), so the age model is an interpolation between those dates (with the core top set to 0 yr) (Figure 5.1.3-1). The overall sedimentation rate is about 1.3 cm/100 yrs, which is similar to Big Lake

The basal ca 35 cm of the core consists of sand, clay, silt, and rocks, above which is about 15 cm of gray sticky clay (ca. 219-168 cm) (Figure 5.1.3-2). Carbonates were not observed in the core, but the $\delta^{13}C$ data from this level (see Section 5.3.4. below) strongly suggests its presence, which would be consistent with loess deposition or possibly an ephemeral lake. Above this, starting abruptly at about 168 cm, silty gyttja and then gyttja dominate the core. Extrapolating from the nearest radiocarbon date about 10 cm higher in the core, the transition to silty gyttja occurred roughly 13,000 cal yr BP and marks the onset of a perennial lake. The gyttja is initially light-colored, but darkens up-core, indicating increased organic deposition through time. Two tephras are preserved in the core, a 4-9.5 cm thick continuous layer at 80-85 cm (ca. 3,800 cal yr BP) and a 0.5 cm thick layer at 39 cm (ca. 2,200 cal yr BP). The MS data from this core clearly show these tephras (Figure 5.1.3-3). In addition, the abrupt MS shift at 168 cm marks the boundary between gray sticky clay and the overlying lake sediments (silty gyttja). MS is lowest about 150-120 cm (ca. 11,000-7,500 cal yr BP) and increases slightly in the non-tephra layers higher in the core.

5.2. Tephra Identification and Correlation

Tephras collected from the cores were confirmed by the presence of glass shards or pumice grains and/or glass coatings on minerals and mineral fragments. For very fine-grained samples (<0.063 mm), confirming volcanic glass was not possible using traditional microscopic techniques and thus such samples are only presumed to be volcanic until high resolution microscopy, such as scanning electron microscopy, can be used to visualize these samples.

All tephra and presumed tephra samples are listed in Appendix A. Depths are given in cumulative depth below sediment-water interface, not drive depths. Ages are based on either radiocarbon modeled ages (Deadman, Sally, Big lakes) or individual radiocarbon ages (Clarence Lake). Basic descriptions of the tephra layers within the cores as well as characteristics of the juvenile glass component of the sampled units are given in Appendix A.

Glass compositions were compared among lakes and with a database of major-element compositions of reference tephras found in terrestrial sections in the Susitna River valley. Refer to Section 6.1 for a discussion of Susitna River valley reference tephra. All tephras from our cores and from Susitna River valley reference tephra have rhyolite composition glass with some tephras exhibiting minor sub-populations of dacite or low-silica rhyolite composition glass (Figure 5.2-1). Geochemical similarity was gaged using the weighted similarity coefficient (SC) of Borchardt (1974), as well as ternary and binary plots. Similarity Coefficients of ≥0.95 is often indicative of correlative tephras.

5.2.1. Clarence Lake

Clarence core 14CL-1 contains five confirmed tephras (AT-3385, AT-3461, AT-3400, AT-3401, AT-3403) and 5 layers too fine-grained to confirm as volcanic at this time (AT-33399, AT-3402, AT-3404 to AT-3406). Clarence core 14CL-2 contains six confirmed tephras (AT-3388, AT-3462, AT-3392, AT-3393, AT-3395, and AT-3396) and two layers too fine-grained to confirm as volcanic at this time (AT-3391 and AT-3394). See the stratigraphic section shown in Figure 5.1.1-1 for the location of the 14CL-1 and 14CL-2 tephras in core 14CL-2.

Only two tephra in 14CL-1 were geochemically analyzed based on adequate particle size (AT-3385 and AT-3461), while the remaining 8 layers remain unanalyzed at this time. Five tephras from 14CL-2 were geochemically analyzed (AT-3388, AT-3462, AT-3392, AT-3395 and AT-3396) and only three remain unanalyzed. Of those samples with geochemistry, only two tephras correlate between 14CL-1 and 14CL-2 cores and of these, only one correlates to Susitna River valley reference tephra (Figure 5.2.1-1A).

The upper most tephras from both cores (AT-3385 and AT-3388) correlate with each other with a SC of 0.99 but do not correlate to any reference tephras collected from the landscape in the Susitna River valley. The 4-cm thick prominent tephra found at about 100 cm depth in both cores correlate (AT-3461 and AT-3462) both geochemically and in physical appearance in the core. This thick tephra was subsampled to check for chemical zonation or the possibility that it may be a composite of multiple tephra layers erupted over time from the same volcano. There is definite geochemical spread within these subsamples although all analyses correlate with very high SC (0.95-0.99) (Figure 5.2.1-1A). All samples of this 4-cm thick tephra correlate to the Watana tephra, a widespread tephra found in terrestrial sections in the Susitna River valley. Sample AT-3392 at 224.5 cm depth does not match any Susitna River valley reference tephra. Samples AT-3395 (289 cm depth) and AT-3396 (330.5 cm depth), the lowest two tephra in the section, are geochemically identical to the 4-cm thick Watana tephra found in both cores which is confusing and suggests that eruptions from the same source volcano occurred more 11,000 cal yr BP ago or (less likely) that the core was contaminated with younger Watana tephra during the coring process.

5.2.2. Deadman and Big Lakes

Deadman core 14DL-1 contains five confirmed tephras (AT-3378–AT-3384). Samples AT-3380–3382 are sequential 1–2 cm subsamples of a single 4-cm thick tephra deposit at 142–146 cm depth. All tephra from this core were geochemically analyzed. Of the five tephra layers, only one correlates to terrestrial references tephra from the Susitna River valley. The 4-cm thick prominent tephra found at about 142–146 cm depth correlates with the Watana tephra, a widespread tephra found in terrestrial sections in the Susitna River valley (Figure 5.2.1-1B). The remaining four tephras are unknown. Correlations with tephras found in Clarence and Sally lakes is presented in figure 5.2.4-1. See the stratigraphic section shown in Figure 5.1.2-2 for the locations of tephras from 14DL-1.

Big Lake core 14BL-A contains four confirmed tephras (AT-3429, AT-3430, AT-3466, and AT-3434). Samples AT-3431–3433 are subsamples of a single 4-cm thick tephra deposit (AT-3466) at 80-84 cm depth (see Appendix A for subsample descriptions). All tephra from this core were geochemically analyzed. Of the five tephra layers, only one correlates to terrestrial references tephra from the Susitna River valley. The 4-cm thick prominent tephra found at 80-84 cm depth correlates with the Watana tephra, a widespread tephra found in terrestrial sections in the Susitna River valley (Figure 5.2.1-1B). The remaining three tephras are unknown. Correlations with tephra found in Clarence and Sally lakes is presented in figure 5.2.4-1. See the stratigraphic section shown in Figure 5.1.2-5 for the locations of tephras from 14BL-A.

Only two tephras correlate between Deadman and Big Lake cores, the 4-cm thick Watana tephra (SC 0.97–0.99) and an unknown tephra, AT-3379 in Deadman and AT-3430 in Big Lake (SC of 0.98).

5.2.3. Sally Lake

Sally core 14SL-3 contains two tephras (AT-3408 and 3463/3464/3465). A single prominent tephra was sampled three times in three separate drives (AT-3463 [Drive 1], AT-3464 [Drive 4], and AT-3465 [Drive 5]). The tephra varies between 4 and 9.5 cm thick, though the thickest tephra is at the top of Drive 5 and the extra 4 cm could be due to tephra falling into the core hole. Samples AT-3409–3411 are subsamples of the prominent 4-5 cm thick tephra, AT-3463 in Drive 1 (see Appendix A for subsample descriptions). Samples AT-3412–3414 are subsamples of the prominent 4-5 cm thick tephra, AT-3464 in Drive 4 (see Appendix A for subsample descriptions). Samples AT-3415–3424 are sequential 1-cm subsamples of the 9.5 cm thick prominent tephra, AT-3465 in Drive 5. All tephra from this core were geochemically analyzed. Of the two tephras, only the prominent 4–9.5 cm thick tephra correlates with references samples of the Watana tephra from the Susitna River valley (Figure 5.2.1-1C). The other tephra is unknown. See the stratigraphic section shown in Figure 5.1.3-2 for the locations of tephras from 14SL-3.

5.2.4. Tephra correlations among lakes

The Watana tephra is the only tephra that correlates among all four lakes in this study. An unknown tephra near the top of Clarence (AT-3388/3385), Big (AT-3429) and Sally lakes (AT-3408) correlates among these three lakes (SC of 0.96–0.98) but not with any references tephra from the Susitna River valley (Figure 5.2.4-1). Another unknown tephra in Deadman Lake (AT-3379) correlates with Big Lake tephra AT-3430 (SC of 0.98) but does not correlate with any references tephra from the Susitna River valley (Figure 5.2.1-1D). In total, only three tephras could be correlated among lakes cored in this study and a total of nine confirmed tephras are unknown and not correlated to any tephras from our lake cores or to references tephra from the Susitna River valley. Since very-fine grained tephras could not be geochemically analyzed, it is possible that other correlations among lakes exist but more work is needed to assess similarity.

5.3. Sediment Geochemistry

Stable carbon and nitrogen isotopes as well as %C, %N, and C:N were analyzed at all four lakes.

5.3.1. Clarence Lake

The sediment geochemistry data from Clarence Lake can be visually divided into three time phases (zones) (Figure 5.3.1-1). Starting from the base of the core, the base to ca. 300 cm ($\geq$12,000 cal yr BP) is characterized by relatively low %C and %N values and some peaks in C:N, which exceed a ratio of 10 and therefore indicate time points when there was greater input of terrestrial organic matter.

The second phase is from ca. 310 cm to 240 cm (~12,000 to ~9,000 cal yrs BP) and is represented by a sharp decrease in δ^{13}C values, a nominal increase in δ^{15}N values, a marked increase in organic content (%C and %N increase) and a decrease in C:N values. The C:N values for this entire phase are below 10 and indicate a primarily autochthonous (within lake) organic matter source during this phase. The δ^{13}C values of this organic matter are very low for the record and relative to a typical value for C3 photosynthesis using an atmospheric carbon source. These lines of evidence suggest autochthonous primary production in a non-carbon limiting environment, which would translate into the lake likely being relatively deep during this phase. It is also during this phase that the core contains the highest %C and %N values, indicating that the autochthonous primary production was high.

The final phase for Clarence Lake above 240 cm (after ~9,000 cal yr BP) shows a gradual increase in the δ^{13}C values and the C:N values, which indicate an increasing representation of organic matter from a terrestrial source (allochthonous - i.e. outside of lake) being mixed in with the autochthonous organic matter production. Between ca. 140 and 130 cm there is a slight decrease in the C:N values indicating a period of decreased terrestrial organic matter input. Although there are some changes in the δ^{15}N values of the core (most notably the slight increase at the base of the core and a slight increase at ~8,500 cal yr BP) the values are relatively low (mean = 1.5 per mil) and do not provide any convincing evidence for significant input of marine derived nutrients (i.e. salmon).

5.3.2. Deadman Lake

The sediment geochemistry data from Deadman Lake can be visually divided into three time phases (zones) (Figure 5.3.2-1). Starting from the base of the core: the base to ~11,000 cal yr BP portion is characterized by relatively low %C and %N values and the lowest C:N values, which are below 10 and therefore indicate autochthonous primary production. The δ^{13}C values of this organic matter are low for the record and relative to a typical value for C3 photosynthesis using an atmospheric carbon source. These lines of evidence suggest autochthonous primary production in a non-carbon limiting environment, which would translate into the lake likely being relatively deep during this first phase. In these respects this phase is similar to the second phase documented in Clarence Lake, although in Clarence Lake the lowest δ^{13}C values correlate with some of the lowest %C and %N values.

It is during the second phase at Deadman Lake from 10,000 to ~6,000 cal yrs BP that the %C and %N values increase markedly along with the C:N values. In contrast to Clarence it appears that this increase in organic content is primarily driven by input from allochthonous production, rather than autochthonous.

The third phase of Deadman Lake shows an initial decrease in C:N values between ~5,500 to 4,500 cal yrs BP, implying a period of decreased terrestrial organic matter input. This feature is similar in timing to the same feature in Clarence Lake. As in Clarence Lake, the upper part of Deadman Lake shows a gradual increase in C:N values from ~5,500 cal yr BP. Although there are some changes in the $\delta^{15}N$ values of the core (most notably the slight increase at the base of the core and two peaks later in the record), the values are relatively low (mean = 2 per mil) and do not provide any convincing evidence for significant input of marine derived nutrients (i.e. salmon). .

5.3.3. Big Lake

The sediment geochemistry data from Big Lake can be visually divided into three time phases (zones) (Figure 5.3.3-1). Starting from the base of the core: the base to $\geq$11,000 cal yr BP is characterized by very low %C and %N values and relatively low C:N values, which are $\leq$10 and therefore indicate a period when the limited amount of organic matter was primarily derived from an autochthonous source.

The second phase is from ~11,000 cal yrs BP to ~9,500 cal yr BP and is represented by a sharp decrease in $\delta^{13}C$ values, a gradual and slight decrease in $\delta^{15}N$ values, a marked increase in organic content (%C and %N increase) and low in C:N values. The C:N values for this entire phase are $\leq$10 and indicate a primarily autochthonous organic matter source during this phase. The $\delta^{13}C$ values of this organic matter are very low for the record and relative to a typical value for C3 photosynthesis using an atmospheric carbon source. These lines of evidence suggest autochthonous primary production in a non-carbon limiting environment, which would translate into the lake likely being relatively deep during this phase. It is also during this phase that the core contains shows the highest %C and %N values, indicating that the autochthonous primary production was high. In this regard Big Lake seems to have limnologically evolved in a manner very similar to Clarence Lake.

The final phase for Big Lake begins after ~9,500 cal yr BP and shows a gradual increase in the $\delta^{13}C$ values and the C:N values, which indicate an increasing representation of organic matter from a terrestrial source (allochthonous) being mixed in with the autochthonous organic matter production. There is no indication of a decrease in the C:N values after 5,500 cal yrs BP that was evident in the Clarence Lake and Deadman Lake records (above). However, it is worth noting that the chronology for Big Lake is more compressed between 7,000 and 4,000 cal yrs BP and therefore this feature might have not been revealed by the sampling resolution adopted for Big Lake. Although there are some changes in the $\delta^{15}N$ values of the core (most notably the relatively high values at the base of the core) the values are relatively low (mean = 2 per mil) and do not provide any convincing evidence for significant input of marine derived nutrients (i.e. salmon).

5.3.4. Sally Lake

As with the other cores described above, the sediment geochemistry data from Sally Lake can be visually divided into three time phases (zones), although there are some features of this record that are starkly different from the other cores (Figure 5.3.4-1). Starting from the base of the core (equating to ~>12,000 cal yr BP) to ~160 cm, the core's base is characterized by very low %C and %N values, exceedingly high C:N values and exceedingly high $\delta^{13}C$ values (up to -12 per mil - note the scale break). Despite the samples being acid fumed to remove carbonate, the very high C:N values and high $\delta^{13}C$ values indicate that carbonate was still present in the sediment analyzed and at large quantities. Visual inspection of the material composing this part of the core showed it to be composed of a fine grey matrix that may have been loess, which can contain carbonate. There was no visual evidence of biogenic carbonates such as ostracods or fingernail clam shells.

The second phase is ~160 cm to ~115 cm (~11,000 to ~7,000 cal yr BP) and is represented by a sharp decrease in $\delta^{13}C$ values, a gradual and slight decrease in $\delta^{15}N$ values, a marked increase in organic content (%C and %N increase) and relatively low in C:N values. The mean C:N values for this entire phase is 11 and indicates a primarily autochthonous organic matter source during this phase, although it does indicate a slightly greater terrestrial organic matter input relative to similar phase of the lakes described above. The $\delta^{13}C$ values of this organic matter are very low for the record and relative to a typical value for C3 photosynthesis using an atmospheric carbon source. These lines of evidence suggest autochthonous primary production in a non-carbon limiting environment, which would translate into the lake likely being relatively deep during this phase. It is also during this phase that the core contains the highest %C and %N values, indicating that the autochthonous primary production was high. In this regard Sally Lake seems to have limnologically evolved in a very similar to Clarence and Big Lakes.

The final phase for Sally Lake begins after ~115 cm (~7,000 cal yrs BP) and shows a gradual increase in the $\delta^{13}C$ values and the C:N values, which indicate an increasing representation of organic matter from a terrestrial source (allochthonous) being mixed in with the autochthonous organic matter production. $\delta^{15}N$ values increase from ~80 cm to the top of the core during this final phase. Although there are some changes in the $\delta^{15}N$ values of the core the values are relatively low (mean = 2 per mil) and do not provide any convincing evidence for significant input of marine derived nutrients (i.e. salmon).

5.4. Palynology and Vegetation Reconstruction

5.4.1. Clarence Lake

The pollen record from Clarence Lake (core 14CL-2) spans more than 11,000 cal yr BP (and probably significantly more) and reflects the changing vegetation from deglaciation until the present.

For simplicity, the Clarence Lake pollen diagram (Figure 5.4.1-1) is divided into three zones, CL-1, CL-2, and CL-3. CL-1 spans from 355 cm (the base of the pollen record) to 270 cm. The pollen record base dates roughly at least 11,000 and perhaps 13,000 or 14,000 cal yrs BP. At the bottom of the core, birch pollen percentages are increasing from 60% to 80%, this probably marks the migration of birch into upper Susitna valley. Birch pollen dominates zone CL-1, with willow and sedges as secondary components. *Artemisia* (sage or wormwood) and grass pollen are present, but in lower frequencies. Fern spores are absent in the bottom of the zone but become more common towards the top. The vegetation in this zone was a birch-dominated shrub tundra, but willows were also a significant component. Sedge, grass, and *Artemisia* dominate the herbs, with ferns becoming more prominent in the latter half of the zone.

Zone CL-2 spans from ca. 270 cm to 180 cm and dates between the early to middle Holocene. Birch pollen continues to dominate, followed willow and sedge pollen, and then by *Artemisia* and grass pollen. The key feature of this zone is the presence of cottonwood/aspen pollen and *Ceratophyllum* spines. Both taxa suggest warm summer temperatures (discussed further below in Section 6.2). Despite the presence of cottonwood on the landscape, the vegetation remained a birch and willow shrub tundra, but with scattered cottonwood stands, possibly around the lake or at its outlet.

Zone CL-3 spans from 180 cm to the core top and dates from the middle Holocene to the present. Birch pollen declines in this zone but continues to dominate, while alder, and then spruce pollen increase. Cottonwood/aspen pollen also declines, as does willow pollen. *Artemisia*, grass, and sedge pollen continue as before. Both spruce and alder pollen are widely distributed by their source plants and as a rule, 5% or 10% spruce and 20% alder pollen indicates they were present locally (Hu et al., 1993; Anderson and Brubaker, 1986). Spruce was certainly present at 5412 cal yr BP (at ca. 115 cm), as that date is on a spruce needle. At Clarence Lake, 5% spruce maybe the most reasonable threshold for local presence as spruce pollen declines to 5% at the core top and very scattered spruce are present around the lake today (Figure 3.1.1.-3). Using the 5% threshold for spruce, it was locally present by about 170 cm, slightly after alder which crosses the 20% threshold at 180 cm. The vegetation was still a shrub tundra, but with birch and alder. It is unclear whether birch trees were present. As a rule of thumb, if spruce is growing locally, then birch trees were probably also present, but probably not abundant. In the top 50 cm in the zone, spruce pollen decreases from 10% to 5% and probably indicates reduced spruce presence in the Clarence Lake watershed.

5.4.2. Deadman Lake

The pollen record from Deadman Lake (core 14DL-1) probably spans 14,000 cal yr BP and documents shifts in the shrub tundra since the formation of the lake.

The record is divided into two zones (DL-1 and DL-2) which reflect the major pollen shifts in the core (Figure 5.4.2-1). Zone DL-1 spans from the record base (235 cm) to ca. 205 cm; ca. 14,000 to 9,800 cal yrs BP. Birch pollen increases from 20% to 80% and then decreases to about 50% at the top of the zone. At the base of the zone, when birch pollen has the lowest frequencies, willow, *Artemisia*, sedge, and grass pollen are at their highest frequencies which then decrease as birch increases. This relationship is an artifact of the percentage calculation; influx measurements (grains/cm^2/yr) indicate that as birch pollen becomes more abundant, the other pollen taxa do not decrease at the same time (Figure 5.4.2-2), indicating increased plant coverage, probably in areas that were unvegetated earlier. Other pollen taxa, such as club moss and fern spores are present throughout the zone. The vegetation was a birch and willow shrub tundra with an understory of sedges, *Artemisia*, club moss, and ferns.

Pollen zone DL-2 (205-0 cm; ca. 9,800 cal yr BP to the present) is marked by increased spruce and alder frequencies. Spruce pollen crosses the 5% threshold about 9800 cal yr BP (which is several millennia earlier than at any of the other lakes), but reaches its maximum frequency of about 20% by about 5700 cal yr BP, after which it decreases to about 5%. Alder pollen crosses the 20% threshold at the beginning of the zone and remains at this level throughout the remainder of the core. Willow, *Artemisia*, and grass pollen are present in low frequencies in the first half of the zone, but increase slightly after about 3,500 cal yr BP (Figures 5.4.2.-1 and -2). Spore-producers are present in moderate frequencies throughout the zone. The vegetation during this zone was a birch, alder, and willow shrub tundra with varying amounts of spruce. Spruce was probably present (if very rare [as it is today]) about 9800 cal yr BP, but was more common than today ca. 6,000 to 5,000 cal yrs BP, after which it decreased, so that by today, only a very few trees are present in the watershed (when spruce pollen frequencies are about 5%). Herbaceous taxa become more abundant in the upper half of the zone, possibly expanding into previously unvegetated areas.

5.4.3. Sally Lake

Only the upper ca. 115 cm of the Sally Lake core (14SL-3) were analyzed for pollen because the interest was in the history of spruce among all the lakes in the study (Figure 5.4.3-1). The lowest analyzed sample is dominated by birch pollen (about 80%), with minor amounts of alder, willow, and other taxa. Subsequently, both spruce and alder pollen increase with spruce frequencies crossing the 5% threshold and alder crossing the 20% threshold (indicating local presence) about 6,000 cal yr BP. Afterwards, spruce and alder frequencies remain high until the top of the core. Influx measurements indicate changes in the abundance of pollen production over the past 6,000 cal yr (Figure 5.4.3-2). Influx is highest (ca. 10,000 grains/cm2/yr) between about 4,000 and 2,000 cal yrs BP; afterwards influx decreases for all taxa, although influx calculations are very sensitive to the age model and interpretations must be made with care. In terms of vegetation, the data suggest the presence of spruce and alder at Sally Lake by about 6,000 cal yr BP, though spruce was probably not widespread until later, say by about 5,000 cal yr BP. In essence, the vegetation around Sally Lake has been boreal forest with varying amounts of spruce since about 6,000 cal yr BP. After about 2,000 cal yrs BP, the lowered pollen influx could reflect lowered pollen production (due to either less dense vegetation or an increased reliance on vegetative reproduction), if it is not an artifact of the age model.

5.5. Diatoms

The text below is modified from a report submitted by Dr. Emilie Saulnier-Talbot.

The Clarence Lake diatom record (Figure 5.5-1) can be divided into two main periods: the first, older, section of the core (357-170 cm) (below thick zone line in Figure 5.5-1), is largely dominated by the planktonic (water surface-living) taxon Aulacoseira subarctica (up to 72% relative abundance). This taxon is associated with deep, productive (high nutrient) subarctic lakes (e.g. Gregory-Eaves et al. 1999; Moos et al. 2009). Its dominance in the older section of the core indicates that Clarence Lake was much deeper and more productive than today. The rest of the assemblage in this section is composed of other planktonic species, including Stephanodiscus minutulus, S. parvus, Asterionella formosa and Discostella pseudostelligera. This section of the record can be subdivided into 4 sub-zones.

The first sub-zone (zone 1; 357-330 cm) is strongly dominated by A. subarctica. Small Fragilaria sensu lato (Staurosira construens var. venter, Pseudostaurosira brevistriata, Staurosirella pinnata) are also present in the assemblage.

The second sub-zone in this section (zone 2; 330-313 cm) is particular in that there is a sudden and significant change in the assemblage, with an important increase in species richness (the most diverse of the entire record) and a switch from a dominance of A. subarctica to an assemblage where small tychoplanktonic (water column and bottom-living) Fragilaria sensu lato dominate, along with planktonic cyclotelloid species (Cyclotella tripartita, C. ocellata, Discostella pseudostellligera). Achnanthaceae and Navicualceae are also present in the assemblage. Chrysophyte cyst abundances drop markedly in this sub-zone relative to the preceeding and following sub-zones. The sudden change in assemblage composition in zone 2 indicates a probable (the chronology is not yet well-established) short-lived drop in lake-level, possibly due to a massive drainage event, although increased aridity and associated lake-level drop cannot be ruled out.

In the third sub-zone (zone 3; 313-225 cm), there is a switch back to high relative abundances of A. subarctica, along with high relative abundance of planktonic S. minutulus. S. parvus, Asterionella formosa, D. pseudostelligera and S. pinnata are also notable components of the assemblage. The high relative abundance of the genus Stephanodiscus in zone 3 indicates a highly productive, nutrient-rich ecosystem. This is not uncommon for Alaskan lakes, as Gregory-Eaves et al. (1999) note that diatom floras from Alaska differ from other circumpolar regions in that meso-eutrophic to eutrophic taxa such as Stephanodiscus are present in greater abundances due to higher concentrations of total phosophorus (TP).

The fourth sub-zone (zone 4; 225-175 cm) shows a gradual decrease in abundances of A. subarctica, a drop in S. minutulus and quasi disappearance of S. parvus, along with an increase in S. pinnata. P. brevistriata also reappears in this zone. There is a notable drop in Chrysophyte cyst abundance, which remains low for the remainder of the record. Lower abundances of Stephanodiscus taxa in zone 4 point to decreased productivity in the lake. The second, younger, main section of the core (175 cm to the core top) sees a sudden drastic drop in the abundance of A. subarctica to values <5% and an increase in diatom diversity due to the fact that no one taxa is as dominant in this section of the core. This section of the core is subdivided into two zones. In the first sub-zone (zone 5; 175-100 cm), A. subarctica is replaced by the planktonic Asterionella formosa and D. pseudostelligera. Other notable taxa in the assemblage of this zone include small Fragilaria sensu lato, namely Pseudostaurosira pseudoconstruens, P. brevistriata and Staurosirella pinnata, and benthic (bottom-living) Achnanthes, Navicula and Nitzschia. P. brevistriata and Staurosirella pinnata become the dominant species in the most recent section of the record (zone 6; 100 cm to the core top), as Discostella pseudostelligera abundances progressively decrease and Asterionella formosa disappears altogether.

The profound change in the structure of the diatom assemblage since the mid-Holocene suggests a gradual decrease in lake depth and a significant change in trophic state. As the lake became shallower, it also became more oligotrophic, as suggested by the dominance of small Fragilaria sensu lato in the more recent past. Pseudistaurosira brevistriata and Staurosirella pinnata are tychoplanktonic taxa, meaning that they can either live on the lake floor or in the water column. They are particularly well-adapted to life in highly turbulent conditions, with short growing seasons and low to highly variable nutrient availability (Saulnier-Talbot 2007). Their dominance of the younger diatom assemblage indicates a deterioration of the climate with, in all likelihood, drier, colder and perhaps windier conditions.

The transfer functions developed to infer lake depth, conductivity and total phosphorous (TP) are a simple weighted-averaging model with classical deshrinking, with an r2boot = 0.52-0.53, a strength comparable to those generated from other northern calibration studies (Gregory-Eaves et al. 1999). The three diatom-inferred variables show similar trends throughout the core, with generally higher values in the older section, with the exception of zone 2 where there is a marked drop in values of the reconstructed variables, and progressive decreases from zone 4 to lower values in the more recent past. Reconstructed lake depth indicates an initially deep lake (zone 1) with a sudden drop in lake level (zone 2), followed by an increase back to initial values (zone 3). Lake depth subsequently decreases (zone 4) and stabilizes in the more recent section of the core (zones 5-6). Diatom-inferred conductivity values are initially moderately high (zone 1) and briefly dip to their lowest values (zone 2) before progressively increasing to their highest values (zone 3). They then decrease to moderately high levels (zone 4) before decreasing even further (zone 5). Conductivity values increase again slightly in the most recent past (zone 6). Diatom-inferred TP values are highest at the base of the core (zone 1), followed by a sharp drop to very low values (zone 2) before returning to very high levels (zone 3). Concentrations then decrease somewhat (zone 4) before decreasing to low levels for the remainder of the record (zones 5-6).

The results of the diatom-inferred reconstructions provide information on the magnitude of environmental change throughout the Holocene in the lake and its catchment. The inference models applied to the sedimentary diatom assemblage data were developed for a set of 51 Alaskan lakes distributed along a latitudinal gradient from the South (Gulf of Alaska) to the North (Arctic Ocean) of the state and include lakes from the region of the Alaska Range, where Clarence Lake is located (Gregory-Eaves et al. 1999). It was therefore deemed appropriate to apply the models to the data of this study. The overwhelming dominance of A. subarctica in the bottom section of the core is a concern for the fit of the model because it is only found at a maximum relative abundance of 43 % in the model lake set, whereas it is present in abundances >40% in all (except one) samples of zones 1, 3 and 4 of the Clarence Lake core. Therefore, the inferred values for the older section of the core (i.e. below 170 cm) should be considered with caution, especially for lake depth since they appear greatly overestimated for this variable, at least. The lake levels inferred for this section of the record are in fact much higher than the deepest lakes included in the inference model (33 m), which make them suspect. However, the results for lake depth in the upper section of the core appear to be more reliable and the top-most value for lake depth corresponds exactly to current measured values (11 m), which lends more credibility to the diatom-inferred values in the upper section of the core. While the accuracy of the inferred values appear to be statistically questionable, especially for the lower section of the core, the inferred trends provide a reliable scenario for the magnitude of environmental change which occurred over the past ~ 11 000 years in and around Clarence Lake.

6. DISCUSSION

6.1. Tephra Distribution and Timing

One of the goals of this project is to correlate tephra found in lake cores to tephra found on the landscape to help better constrain the ages of terrestrial deposits. There are three widespread tephra deposits that have been routinely recognized during cultural resource investigations conducted in the Susitna River valley. From oldest to youngest, they are the informally named Oshetna, Watana, and Devil tephras.

The Oshetna tephra ranges in thickness from 3–5 cm and has an age range of 5,960–5,790 ^{14}C yrs BP (ca. 6,800 cal yr BP). (Child et al., 1998).The Watana tephra ranges in thickness from 6–20 cm and has an age range of 2,830–5,270 ^{14}C yrs BP (ca. 2,800–6,000 cal yrs BP) based on radiocarbon ages of numerous paleosols bounding this layer in the Susitna River valley (Dilley, 1988; Dixon et al., 1985, Dixon and Smith, 1990). The Watana tephra has a distinctive upper oxidized component and lower non-oxidized component in subaerial exposures. The Devil tephra is as much as 8-cm thick and is usually found directly beneath the surface organic mat (Dixon and Smith, 1990). The tephra was erupted between 1,516–1,420 ^{14}C yrs BP (ca. 1,500–1,400 cal yrs BP) (Dixon and Smith, 1990).

Reference materials from these three tephra deposits were used in an attempt to correlate tephras from the lake cores in this study to those found on the landscape. Of these three named layers, the Watana tephra was confidently identified in all 4 lakes based on glass geochemistry, physical descriptions, and radiocarbon ages of the deposits. The Oshetna and Devil tephras were not recognized in any of the lakes, however, since many samples were too small to perform geochemical analyses, it is possible that these units are in fact present. It is known that the Devil and Watana tephras are difficult to distinguish from each other petrographically and geochemically, and this was true in this study. However, there is a high degree of confidence in the identification of the Watana tephra and not the Devil tephra based on stratigraphic position and ages within the cores as well as the distinctive oxidized/unoxidized couplet attributed to the Watana tephra.

The age of the prominent 4-9.5 cm thick tephra correlated to the Watana tephra in all four lakes is consistent with other ages for this unit except in Big Lake, where the age is older. The age models are in progress and more radiocarbon dates are needed to make robust age models so there is little concern about the apparently older age of the prominent tephra in Big Lake. Based on geochemical, physical characteristics and position in core, it appears likely that all four lakes contain the same Watana tephra.

6.2. Middle/Upper Susitna Climate and Vegetation after ca. 14,000 cal yr BP

Our study lakes started forming by roughly 14,000 to 12,000 cal yrs BP and they provide limiting ages on deglaciation in the region. This is 1,000 to 3,000 years earlier than previous reconstructions, but not unexpected, given the limited number of study locales and radiocarbon dates from the earlier studies (Reger et al., 1990; Woodward-Clyde Consultants, 1982). During this time, the climate is changing dramatically with increasing warmth and moisture (Bigelow, 2013 and references therein). Once our study lakes started forming, the sediment biogeochemistry data indicates that they began by being productive and relatively deep in all cases, which would have likely supported a productive aquatic food web and its associated resources. The vegetation at this time, shrub tundra, was less productive than modern tundra, as indicated by relatively low pollen influx.

Later, the early Holocene, (ca. 12,000-9,000 cal yrs BP) is marked by warmer than modern summer temperatures, due in part to shifts in the Earth's orbit around the sun. (Berger, 1978). In the western Arctic, the local expression of this warmth varies in both strength and timing (Kaufman et al., 2004), with the strongest warming (up to 6°C) in the Norwegian Sea, and the most delayed warming (ca. 6,000 cal yr BP) at the margins of remnant ice sheets, such as in northeastern Canada. In Alaska, this early Holocene warming (the Holocene Thermal Maximum [HTM]) is reflected in a myriad of climatic proxies, such as increasing lake productivity (Kaufman et al., 2004), changes in landscape dynamics (Mann et al., 2010), and vegetation shifts (Edwards et al., 2005).

In Alaska, the associated vegetation changes are not so much in a spruce tree line advance as elsewhere (such as northwestern Canada), but in the expansion of *Populus* sp. (probably cottonwood) both within its current limits, but also expanding far to the north. On the North Slope, abundant cottonwood logs and leaves have been dated to the early Holocene (Mann et al., 2010; Nelson and Carter, 1987). Today, cottonwood is found mainly south of the Brooks Range, although extralimital stands do grow in protected drainages in the eastern half of the North Slope (Viereck and Little, 1975; Bockheim et al., 2003). Within its current limits, pollen records from across the interior contain a brief but consistent cottonwood/aspen pollen "blip" (Brubaker et al., 2001; Bigelow, 2013), which has lead researchers to hypothesize the presence of a novel biome (a deciduous woodland) across Alaska during the HTM (Edwards et al., 2005)

In our study area, the Clarence Lake pollen record contains an episode of increased cottonwood/aspen pollen frequencies. As *Populus* pollen does not travel far from its source and easily degraded, this indicates the trees were growing near the lake (Edwards and Dunwiddie, 1985). While the radiocarbon dating for Clarence Lake is less than ideal, the extant dates are consistent with an early Holocene age for this zone. A similar cottonwood/aspen blip was not seen at the higher elevation Deadman Lake (although a few pollen grains were encountered), suggesting the expansion did not reach as high as Deadman lake at about 960 m. At Sally Lake (the lowest elevation of the studied lakes), that part of the core is unanalyzed, but presumably also has the cottonwood/aspen blip.

Interestingly, at Clarence Lake, *Ceratophyllum* (presumably *C. demersum*) spines were encountered at the same levels as the increased cottonwood/aspen pollen frequencies. *C. demersum* is an aquatic plant that favors still, relatively shallow waters found at the lake margin. Today, it is found mainly within the boreal forest, although it has been found in couple localities at the spruce limit or just beyond it (Les, 1986; Holmquist, 1971). While it is unknown whether *C. demersum* grows in Clarence Lake today, its presence in the lake during the early Holocene is highly suggestive of warmer than modern summer temperatures during the HTM.

The expansion of spruce across interior Alaska marks a radical change in the landscape for both people and fauna. In interior Alaska, especially in the Tanana valley, spruce were present by about 11,000 cal yr BP (Bigelow and Powers, 2001), though it is slightly later in the tributary valleys (Bigelow and Edwards, 2001). In our study area, the rise in spruce pollen is earlier in high elevation Deadman Lake (ca. 9,500 cal yr BP), than in the lower elevation Sally Lake (ca. 6,000 cal yr BP), or at Clarence lake (sometime around 6,000 cal yr BP). This is unexpected as the obvious route for spruce migration would seem to be up the Susitna valley and further up a side valley to Deadman Lake. However, pollen records from the east (Tangle Lakes and eastern Denali Highway) and southeast (Copper River Basin) indicate spruce grew in those regions by about 10,000 cal yr BP (Ager, 1989 and references therein). This suggests the spruce pollen in Deadman Lake (as well as the trees themselves) originated from stands in those regions and not from the Susitna River basin. In fact, the eastern sites may have been the most likely source as Clarence Lake is in a direct line between Deadman Lake and the Copper River Basin, but the spruce pollen does not increase there until around 6,000 cal yr BP.

Pollen records at two of the lakes (Deadman and Clarence) indicate a reduction in spruce abundance in the late Holocene (after about 4,500 cal yr BP at Deadman, possibly somewhat later at Clarence). In contrast, the Sally Lake record shows no such decline, except maybe at the very top. This indicates that spruce retracted its range at the higher elevations, but that lower elevations (such as at Sally Lake) were largely unaffected. Spruce distribution is strongly correlated with summer temperature (Thompson et al., 1999), and reduced spruce abundance, especially at tree-line, implies summertime cooling. This cooling is consistent with well-documented neoglacial ice advances (after ca. 6,000 cal yr BP) in numerous Alaskan mountain ranges, although they have not been mapped in our region (Porter, 2007).

6.3. Humans and Environment

A major objective of this project was to begin to outline the environmental contexts for understanding changes in the archaeological record of the upper and middle Susitna River Valley. This study provides a major step toward understanding the evolution of Holocene landscapes and provides a context for human responses to ecological and environmental change over the past 14,000 years. It is beyond the scope of this study to assess how transitions in the archaeological record may correspond to changes in the paleoenvironmental record, as this would be a more extensive undertaking. However, this study can provide some directions for future archaeological and paleoenvironmental research that is focused on the human and environment interactions in this region.

6.3.1. Late Pleistocene/Early Holocene

Our work has established that lakes and deglaciation of the upper and middle Susitna River region began, at least, by 12,000 cal yr BP, and possibly as early as 14,000 cal yr BP. However, within the study area, the earliest human occupation currently recognized is the Jay Creek Ridge site's lowest component at 10,700 to 10,900 cal yrs BP (Bowers et al., 2012; Dixon, 1999; Wygal and Goebel, 2012). Wygal and Goebel (2012) suggest that the region and southcentral Alaska was colonized from the northern interior regions, in particular the Nenana and Tanana River Valleys, which have records of human occupation 2,000 to 3,000 years earlier. The current difference between the timing of potentially available landscape attractants, (including lakes and mineral licks), that could be used by animals and humans after deglaciation in the region, and the current record for the earliest occupation in the region, brings up several important research avenues and questions. These include: (1) understanding what potential animal and aquatic resources were available to humans shortly after deglaciation of the region; (2) defining when subsistence resources became stable enough to sustain human occupation in the region; and (3) modeling the process and pathways that humans used to colonize this region, and whether this region could have been a potential gateway for human colonization of south central Alaska.

Currently, there is little information on faunal remains from these early occupations in the Susitna Valley, especially from the upper and middle Susitna River region. The paleoecological information provided here could provide an indirect glimpse into the types of animal resources that were available during the shortly after deglaciation. The palynological records point toward the presence of an herbaceous and shrubby vegetated landscape similar to areas within the Nenana River Valley around 14,000 to 12,000 cal yrs BP (Bigelow and Powers, 2001). Based on the similarity to Late Glacial archaeological and palynological records from the Nenana Valley, it is quite possible that bison and wapiti, even caribou, inhabited the upper and middle Susitna River Valley during this period. However, more archaeological and paleontological work will hopefully test that tentative observation.

Lakes appear to be highly productive once they start forming between 14,000 and 12,000 cal yrs BP. The earliest occupation of this region appears after the formation of many of these lakes; although, it is not currently well understood how and if these earliest occupations used higher altitude lakes, in comparison to the Late Glacial and early Holocene use of lower elevation lakes in interior Alaska (Cook, 1969; Wooller et al., 2012). The currently known archaeological occupations around lake margins in this upper and middle Susitna River Valley occur ca. 6,000 to 5,000 cal yrs BP (Dixon et al., 1985), but it is still unclear if earlier occupations utilized lake resources. In short, there is a dearth of information on earlier sites in the region but the paleoenvironmental information could provide a framework to approach some of the research avenues and questions outlined above.

6.3.2. Middle-to-Late Holocene

There appears to be a hiatus in human occupation in the study area between 10,000 and 6,500 cal yrs BP, at least, and maybe as late as 5,500 cal yr BP (Bowers et al., 2012; Dixon et al., 1985). The middle Holocene period saw dramatic changes in the environment and the archaeological record throughout interior Alaska. The appearance of the Northern Archaic tradition around 6,000 to 5,500 cal yrs BP marks potential shifts in the adoption of new artifact styles (i.e., projectile points) and possibly an introduction of new human populations. Caribou is a dominant presence in the faunal remains throughout Holocene archaeological assemblages, and indicates that this species was a major subsistence focus at least by 6,000 cal yrs BP.

Soil formation appears to increase between 6,000 and 4,500 cal yrs BP, after Oshetna tephra deposition and prior to Watana tephra accumulation (Dixon et al., 1985; Dixon and Smith 1990). This increase in soil formation and abundance of caribou in the archaeological assemblages suggests a certain degree of ecological stability during this period, likely fostering the fruition of North Archaic populations in the region. This stability appears coincident with a rise in spruce pollen in several of the lake cores. As noted above, an increase in tephra deposition occurs in the latter half of the middle Holocene (~5,000-4,000 cal yrs BP) and in the late Holocene (~1,500-1,400 cal yrs BP). It is still unclear what impacts, if any, the deposition of tephras had on the local vegetation, animals and human land use. However, the research theme of how volcanic deposits may affect ecological systems and human land use has been a question for some time in interior Alaskan archaeology (Derry, 1975; Workman, 1974, 1979). In the upper and middle Susitna River Valley, this was a primary research theme in the early research designs of the Susitna Hydroelectric Project cultural resources investigation in the early 1980s (Dixon and Smith, 1990; Dixon et al., 1985; Saleeby, 1984).

As the archaeological, paleoecological, and geologic data sets become more refined in the region, it will become more apparent if changes in vegetation and archaeology may correspond with the timing of tephra deposition. However, several sets of data will need to be refined before this approach and other research avenues mentioned above, are used to any sort of reliable correspondence between changes in the archaeological and paleoenvironmental records. While a large data set of radiocarbon dates on archaeological components exists for the upper and middle Susitna River Valley, many were produced in the 1980s and lack the accuracy and precision that are required to compare archaeological and paleoenvironmental changes (see Bowers et al., 2012 for a summary of the problems with the early radiocarbon dating methods). More recent developments in radiocarbon dating technology, specifically AMS, have provided the ability to date sites and occupations with increased accuracy and precision that makes attempts at correlation with changes in the archaeological and paleoenvironmental records more robust and plausible. In addition, more accurate and systematic identifications and quantitative analyses on faunal and lithic assemblages from this region would allow comparison of potential correlations between changes in the archaeological and paleoenvironmental records.

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8. TABLES

Table 3.1-1: GPS coordinates of the lakes, coring sites, water depth, and ice thickness measurements.

Lake	Locality name	Latitude N (decimal degrees)	Longitude W (decimal degrees)	Water depth (m)	Ice thickness (cm)
Big Lake	14BL-01	62.99889796	-148.1895604	11	120
	14BL-02	62.99898663	-148.1911706	16.5	115
	14BL-03	62.99916616	-148.193546	12	115
	14BL-04	63.00038271	-148.2005284	2.2	
	14BL-05	63.00088932	-148.2054725	1.6	118
	14BL-06	62.99979461	-148.2050753	1.9	
	14BL-07	62.99562587	-148.2036055	8.7	114
	14BL-08	62.99299482	-148.2031432	28	
	14BL-09	62.99166715	-148.1953107	28.9	
	14BL-10	62.99486345	-148.1905257	11.4	
	14BL-11	62.99539061	-148.1906884		
	14BL-A*	62.99540048	-148.190679	17.8	
	14BL-13	62.99542773	-148.1906486		
	14BL-14	62.99889223	-148.1895623	11	
Clarence Lake	14CL-01*	62.6783751	-147.8108158	10.5	103
	14CL-02*	62.67839765	-147.8108029	10.79	
	14CL-03	62.67839114	-147.8108307		
	14CL-04	62.67838813	-147.8108585		105
	14CL-05	62.67840305	-147.8107875	10.79	
Deadman Lake	14DL-01*	63.00591959	-148.2650006	14.05	
	14DL-02	63.00589599	-148.2649853		
	14DL-03	63.00590214	-148.2650723		
Sally Lake	14SL-01	62.83512585	-148.1857926	7.6	91
	14SL-02	62.83558267	-148.1876878	7.55	92
	14SL-03*	62.83559721	-148.1877861	7.55	
	14SL-04	62.83559471	-148.187742		
	14SL-05	62.83560399	-148.187828		
	14SL-06	62.8356209	-148.1878781	7.4	

* indicates coring site

Table 5.1-1: Core depths.

Lake	Core	Drive	Length (cm)	Depth from sediment/water interface (cm)
Clarence Lake	14CL-2	Boliv1	87	0-87
	14CL-2	D1	97	10-107
	14CL-2	D2	90	107-197
	14CL-2	D3	97.5	197-294.5
	14CL-2	D4	65	294.5-359.5
Deadman Lake	14-DL-1	Boliv1	49	0-49
	14-DL-1	D1	99	8-107
	14-DL-1	D2	100	107-207
	14-DL-1	D3	40	207-247
Big Lake	14-BL-A	Boliv1	5	0-5
	14-BL-A	D1	101	18-119
	14-BL-A	D2	98	119-217
	14-BL-A	D3	35	217-252
Sally Lake	14-SL-3	Boliv2	68	0-68
	14-SL-3	D1	95	58-153
	14-SL-3	D4	45	40-85
	14-SL-3	D5	75.5	76-151.5
	14-SL-3	D2	66	153-212

Table 5.2.1-1: Radiocarbon dates from the studied lakes.

Lab#	Lake	Core	Depth in core (cm)	Material dated	δ13C ‰	14C age ± 1 SD	Cal Median	Calibrated 1 SD range Younger limit	Calibrated 1 SD range Older limit	Calibrated 2 SD range Younger limit	Calibrated 2 SD range Older limit
UGAMS-18842	Big Lake	14BL-A	1	Bryophytes	-33.8	520±20	533	523	540	512	551
UGAMS-18843	Big Lake	14BL-A	24-26	Organics	-27.5	450±35	508	494	525	340	540
UGAMS-18844	Big Lake	14BL-A	34-36	Organics	-25.3	1760±55	1674	1571	1733	1559	1817
UGAMS-18845	Big Lake	14BL-A	43-45	Organics	-26.6	2040±40	1998	1934	2049	1899	2116
UGAMS-18846	Big Lake	14BL-A	45-47	Organics	-25.7	2480±40	2576	2490	2707	2379	2724
UGAMS-18847	Big Lake	14BL-A	49-51	Organics	-26.3	2320±25	2343	2335	2351	2313	2358
UGAMS-18848	Big Lake	14BL-A	51-53	Organics	-24.3	2620±30	2752	2741	2761	2725	2778
UGAMS-18849	Big Lake	14BL-A	64-66	Organics	-24	3200±30	3420	3393	3447	3366	3470
UGAMS-18850	Big Lake	14BL-A	109-111	Organics	-28.6	6880±40	7712	7669	7751	7620	7816
UGAMS-18851	Big Lake	14BL-A	180-182	Organics	-27.8	9340±30	10554	10512	10583	10438	10657
UGAMS-18852	Big Lake	14BL-A	190-192	Organics	-26.4	9820±40	11230	11207	11246	11181	11290
UGAMS-19730	Clarence	14CL-2	102-104	Bark	-27.4	3690±25	4035	3982	4082	3929	4141
UGAMS-18753	Clarence	14CL-2	112-116	Organics	-25.9	4870±30	5608	5588	5642	5494	5655
UGAMS-18832	Clarence	14CL-2	116-118	Picea needle (charred)	-27.6	4620±30	5412	5308	5445	5297	5461
UGAMS-18755	Clarence	14CL-2	126-128	Organics	-26.8	5700±25	6477	6440	6501	6411	6549
UGAMS-19731	Clarence	14CL-2	162-166	Plant fragments	-24.2	4770±40	5516	5473	5584	5330	5592
UGAMS-18756	Clarence	14CL-2	272-274	Organics	-28.5	9480±35	10726	10661	10771	10588	11065
UGAMS-18757	Clarence	14CL-2	275-279	Organics	-27.1	9990±30	11446	11327	11600	11285	11613
UGAMS-18754	Clarence	14CL-2	309.5-313.5	Daphnia ephippia	-34.9	9370±70	10593	10510	10690	10300	10768
UGAMS-19732	Clarence	14CL-2	317-318.5	Plant fragments	-27.2	9950±30	11341	11273	11391	11249	11600
UGAMS-18176	Deadman	14DL-1	1-2	Leaf fragments	-28.3	Modern					
UGAMS-18833	Deadman	14DL-1	35-38	Wood and plant fragments	-28.9	340±30	391	318	460	311	480
UGAMS-18834	Deadman	14DL-1	57-59	Wood and plant fragments	-26.7	1010±20	934	922	952	913	963
UGAMS-18835	Deadman	14DL-1	85-88	Wood and plant fragments	-26.0	1770±30	1675	1622	1718	1606	1811
UGAMS-18836	Deadman	14DL-1	114-116	Wood and plant fragments	-28.1	2500±30	2587	2499	2716	2485	2736
UGAMS-18837	Deadman	14DL-1	157-158	Wood	-27.4	4450±25	5079	4975	5263	4966	5280
UGAMS-18177	Deadman	14DL-1	182	Charred wood	-26.0	5430±25	6240	6212	6282	6198	6288
UGAMS-18175	Deadman	14DL-1	210	Charred wood	-27.3	9260±30	10446	10400	10510	10296	10553
UGAMS-20052	Sally	14SL-3	35-39	Pollen	-28.4	2180±20	2254	2160	2301	2123	2306
UGAMS-20053	Sally	14SL-3	88-92	Pollen	-28.4	3740±20	4102	4013	4147	3991	4153
UGAMS-19733	Sally	14SL-3	157-161	Wood	-27.2	10200±35	11903	11818	11987	11758	12061

Table 5.1.2-1: ^{210}PB age models.

Sample ID	Depth (cm)	CRS age model	Linear regression age model	Comments
14DL-1-Pb1	0-0.5	9.7	8.0	
14DL-1-Pb2	0.5-1	17.0	20.4	
14DL-1-Pb3	1-1.5	27.9	32.9	
14DL-1-Pb4	1.5-2	42.8	45.3	
14DL-1-Pb5	2-2.5	56.4	57.3	^{137}Cs maximum inventory in 1966, (48 years ago)
14DL-1-Pb6	2.5-3	70.4	68.2	
14DL-1-Pb7	3-3.5	84.5	81.5	
14DL-1-Pb8	3.5-4	95.1	94.2	
14DL-1-Pb9	4-4.5	118.1	107.2	

9. FIGURES

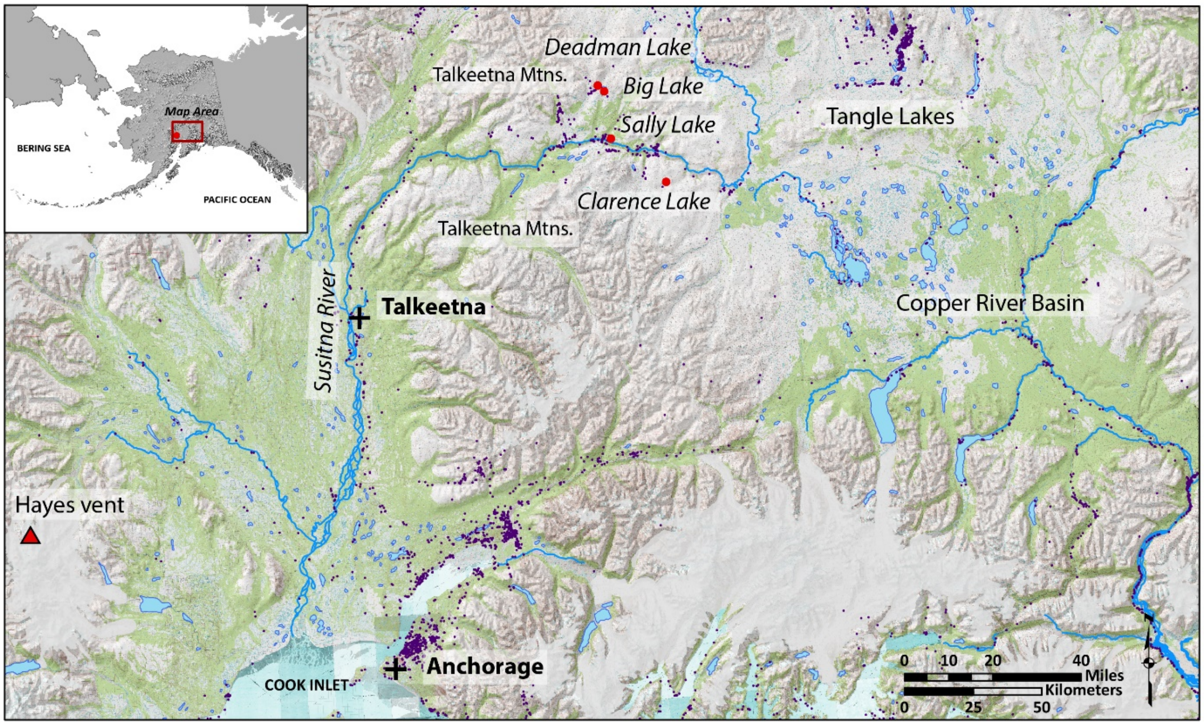

Figure 3.-1: Map of the region showing the study lakes, Hayes vent, and archaeological sites from all time periods (purple dots).

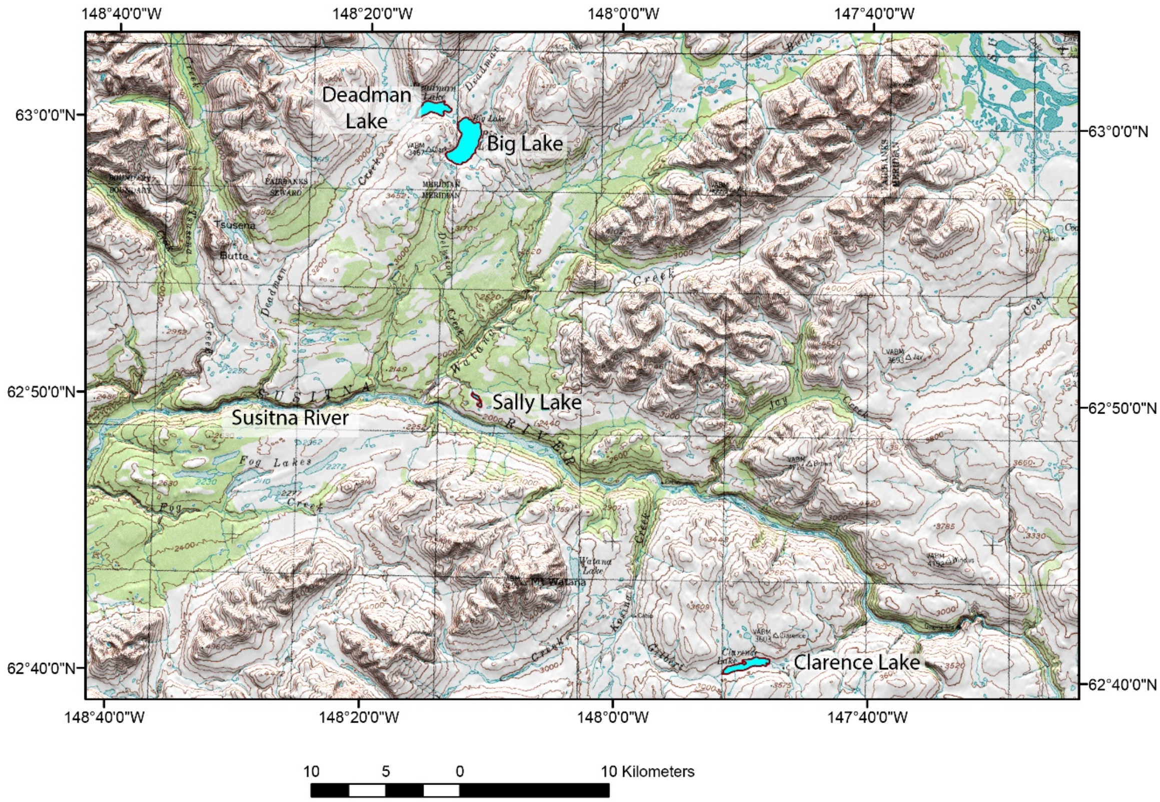

Figure 3.1.1-1: Map of middle/upper Susitna drainage with study lakes.

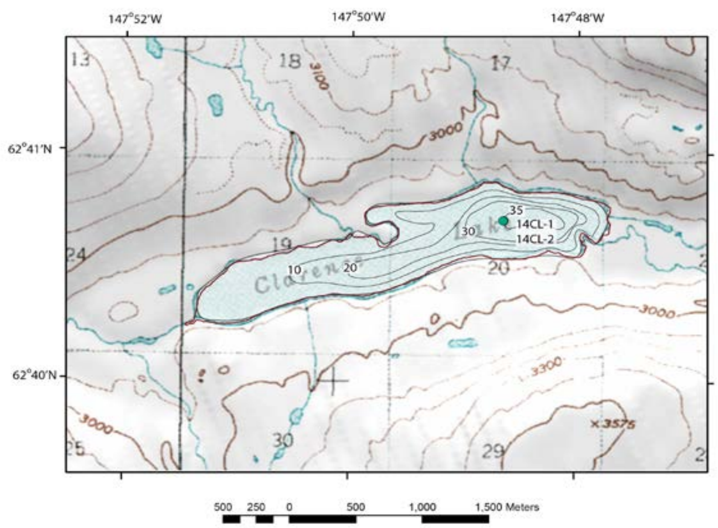

Figure 3.1.1-2: Clarence Lake bathymetry (in feet) and core location.

Figure 3.1.1-3: Clarence Lake shoreline with some of the scattered spruce marked.

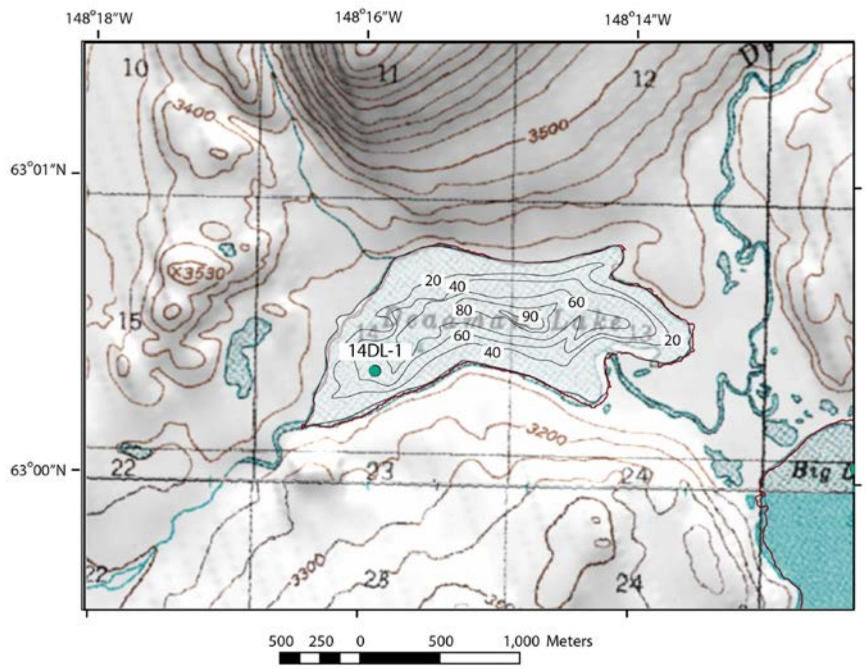

Figure 3.1.2-1: Deadman Lake bathymetry (in feet) and core location.

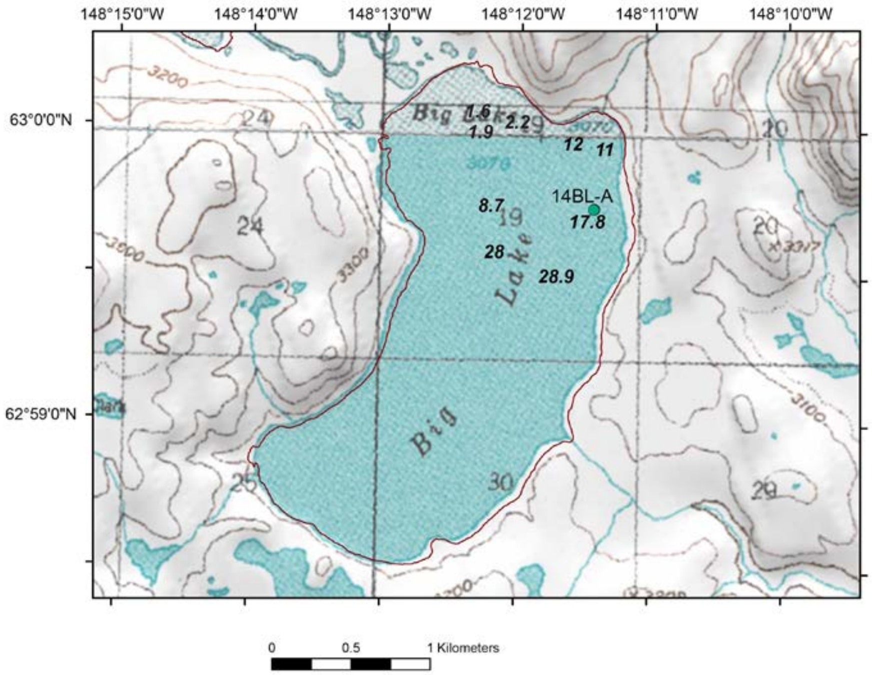

Figure 3.1.2-2: Big Lake water depths (meters) and core location.

Figure 3.1.2-3: Aerial photograph of Big Lake looking towards the southwest.

Tall shrubs are present on the far side of the lake and in the gully on the near side. Deadman Lake is just out of the picture on the right margin.

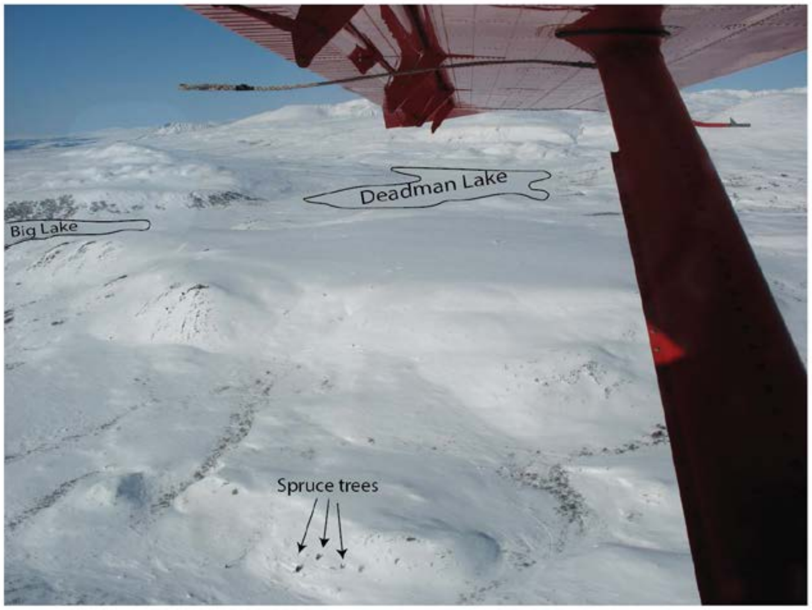

Figure 3.1.2-4: Aerial photography of Deadman Lake and a portion of Big Lake.

Note spruce trees in the foreground. View is to the west.

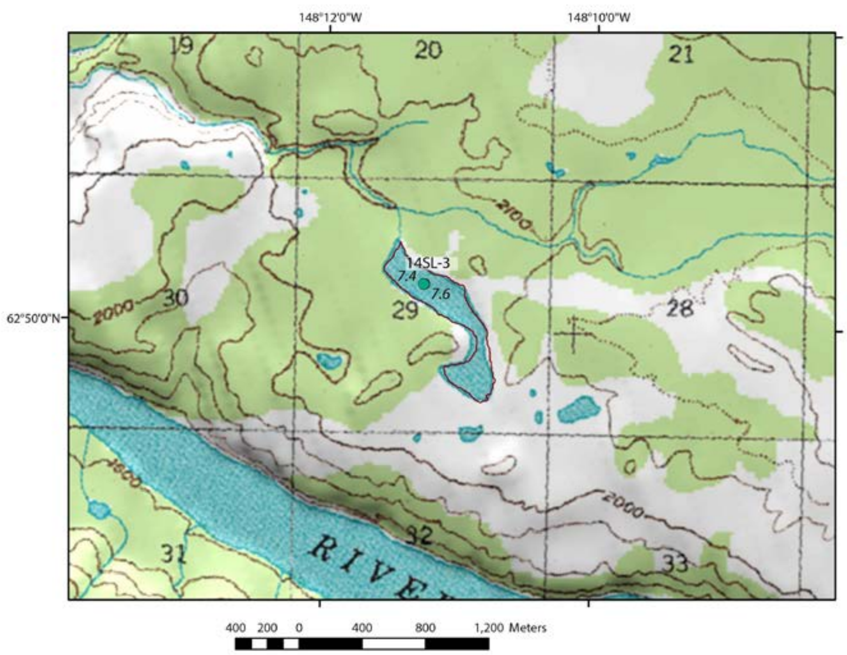

Figure 3.1.3-1: Sally Lake water depths (m) and core location.

Figure 3.1.3-2: Aerial photograph of Sally Lake with the Susitna River in the distance.

Note that the spruce trees are more widely scattered at Sally Lake than in lower elevations. View is to the west.

Figure 4.1-1: Twin Otter taxing to core location at Deadman Lake.

Figure 4.1-2: Augering a hole in the over 1 m thick ice at Big Lake.

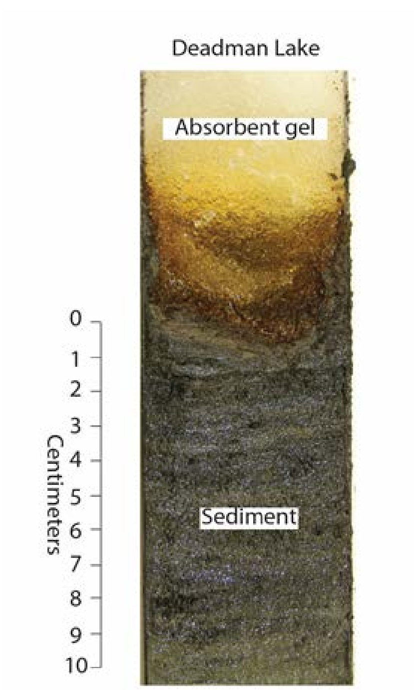

Figure 4.1-3: Absorbent gel stabilizing lake sediment.

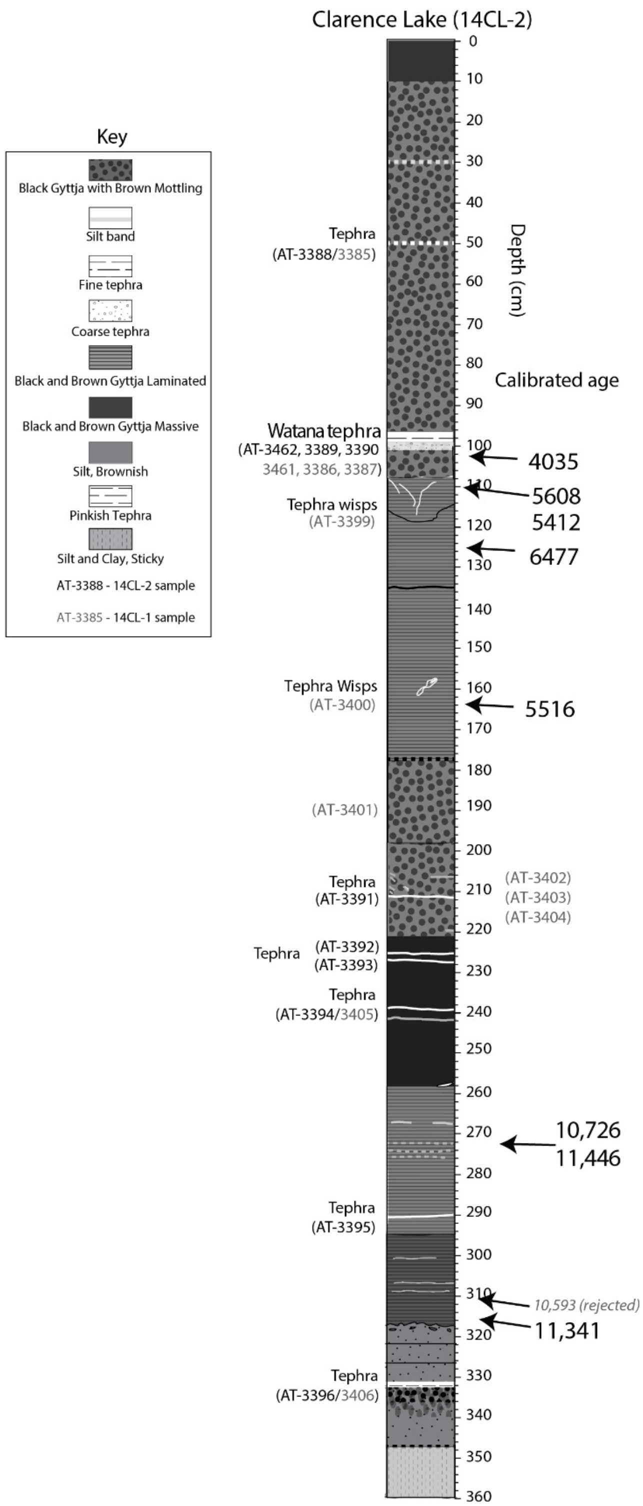

Figure 5.1.1-1: Clarence Lake (core 14CL-2) sediment stratigraphy and calibrated ages.

Note, some tephra samples (in gray text) are from core 14CL-1, which is virtually identical to this core.

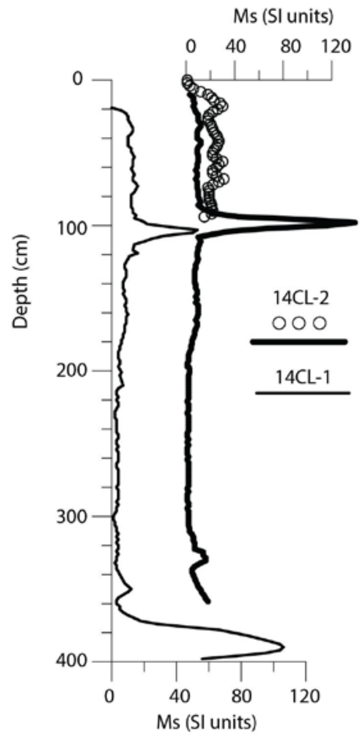

Figure 5.1.1-2: Magnetic susceptibility for Clarence Lake cores 14CL-1 and 14CL-2.

In the 14CL-2 graph, open circles are data from the Bolivia core and closed circles are Livingstone cores. Because the Bolivia core is larger than the Livingstone cores, the MS values are higher.

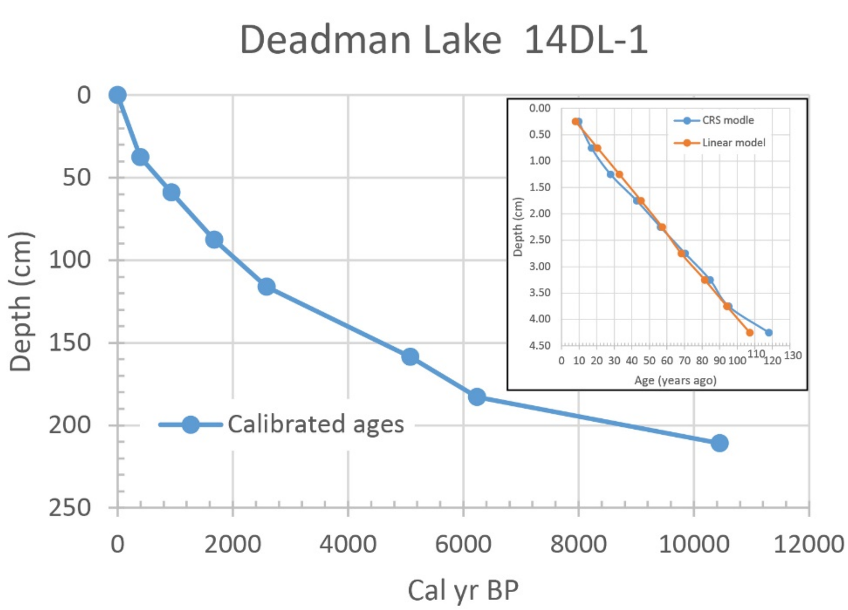

Figure 5.1.2-1: Deadman Lake age-depth graph. Inset figure shows the 210Pb age models for the top 4.5 cm.

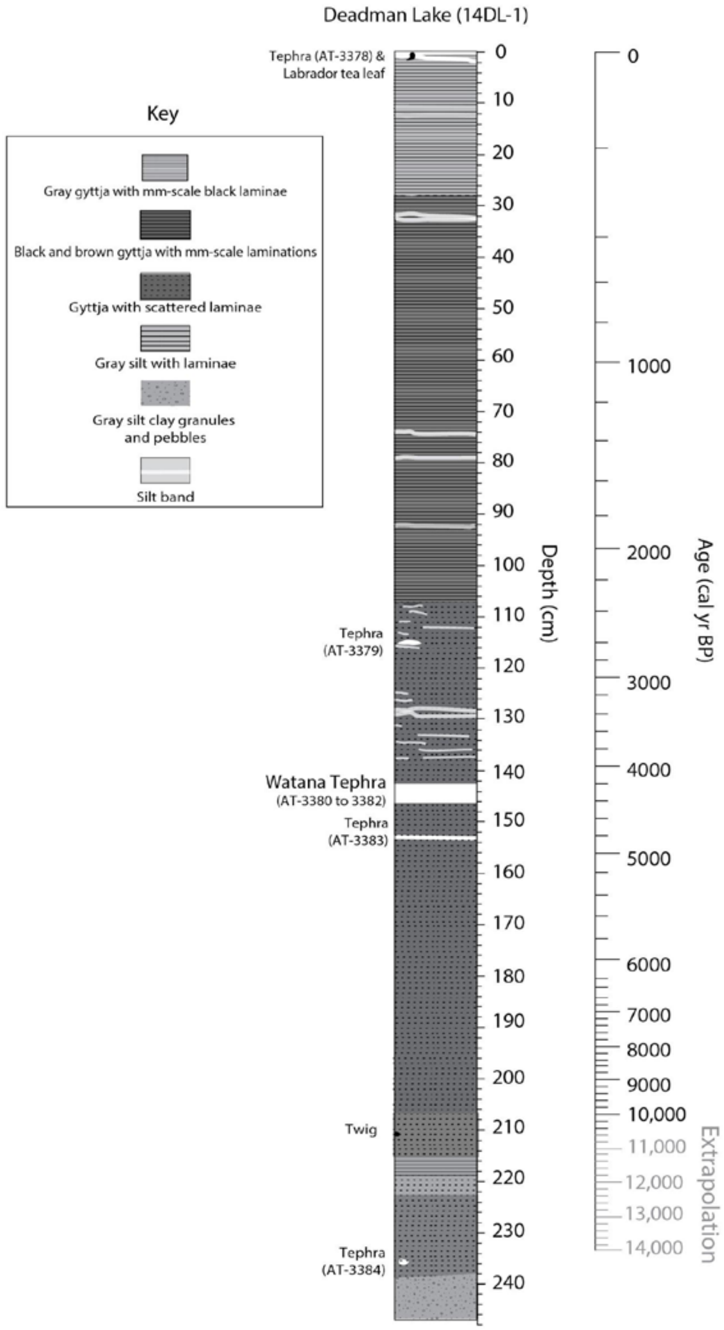

Figure 5.1.2-2: Deadman Lake (core 14DL1) stratigraphy and age model.

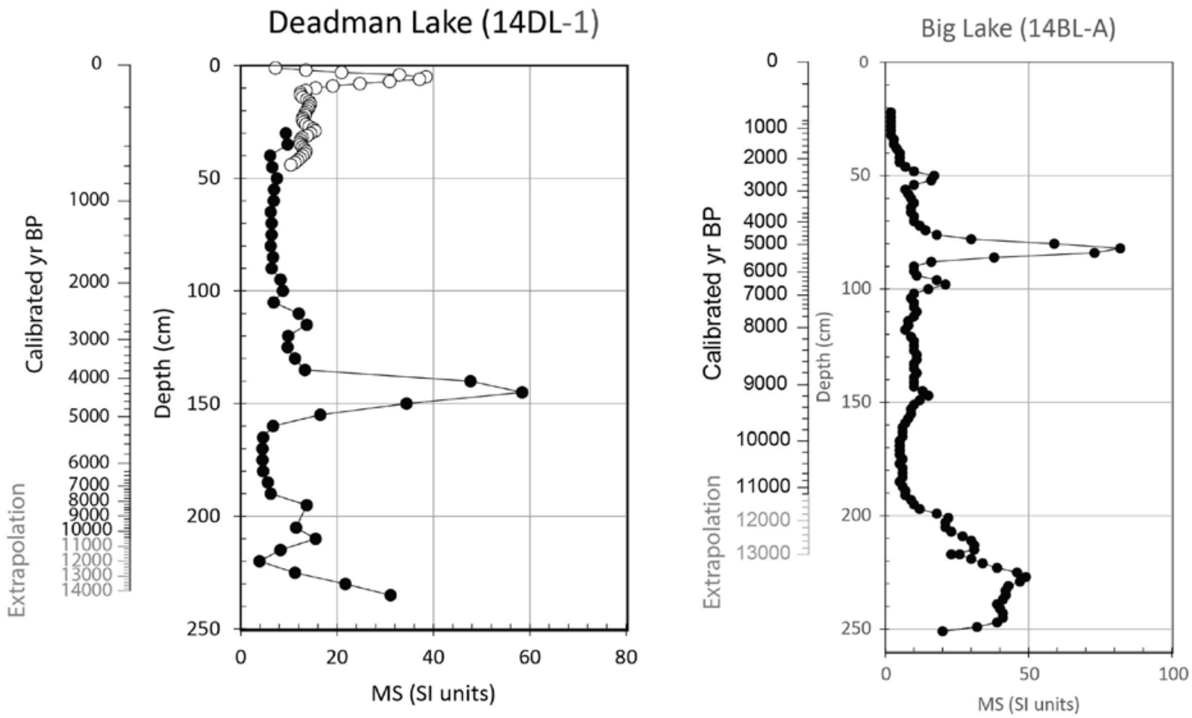

Figure 5.1.2-3: Magnetic susceptibility for Deadman and Big Lakes.

Open circles are data from the Bolivia core and closed circles are Livingstone cores. Because the Bolivia core is larger than the Livingstone cores, the MS values are higher.

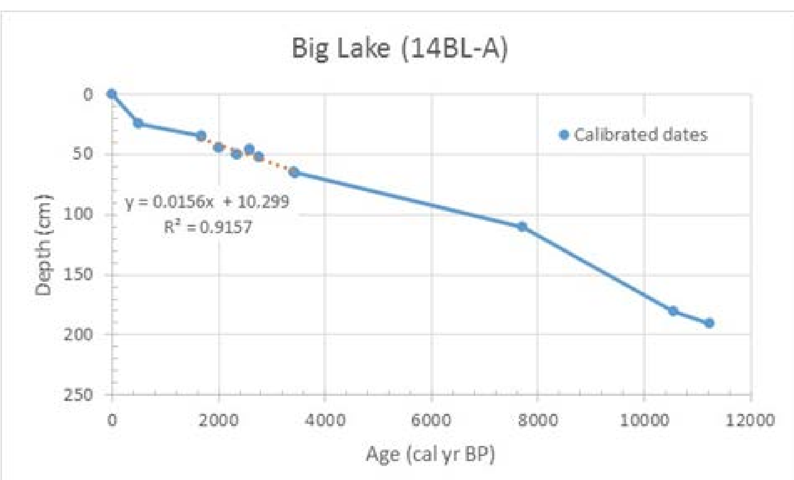

Figure 5.1.2-4: Big Lake age model.

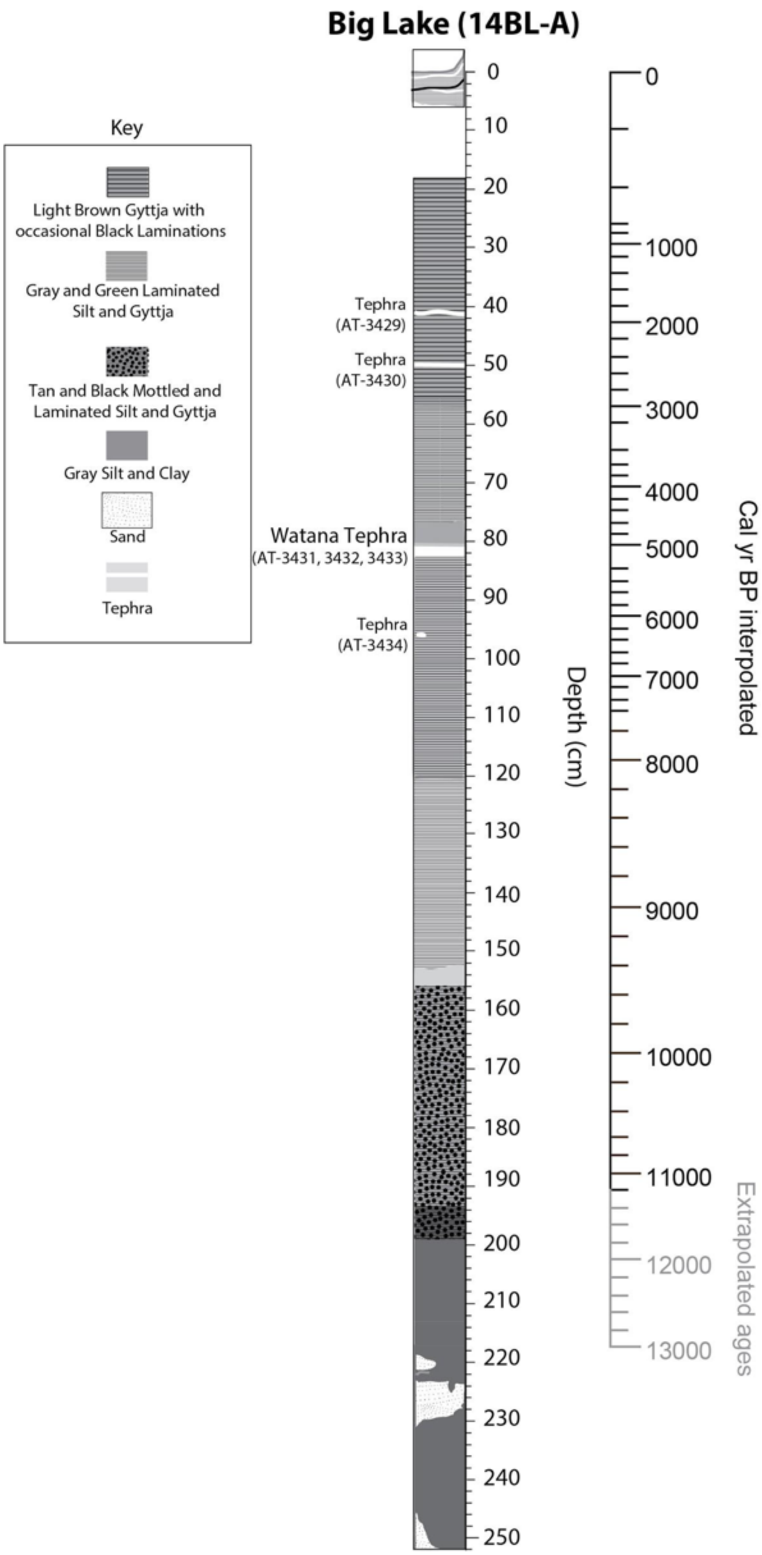

Figure 5.1.2-5: Big Lake core stratigraphy.

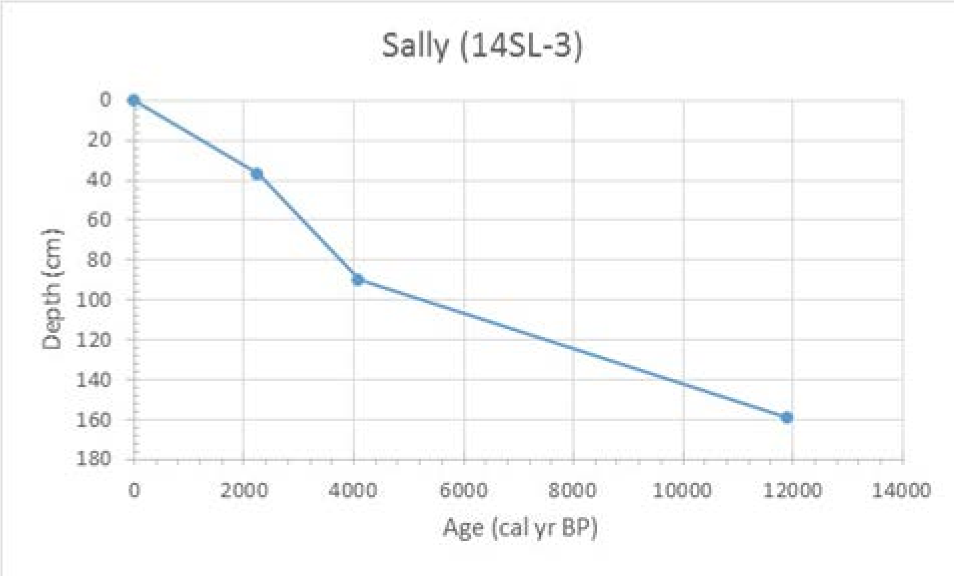

Figure 5.1.3-1: Sally Lake age model.

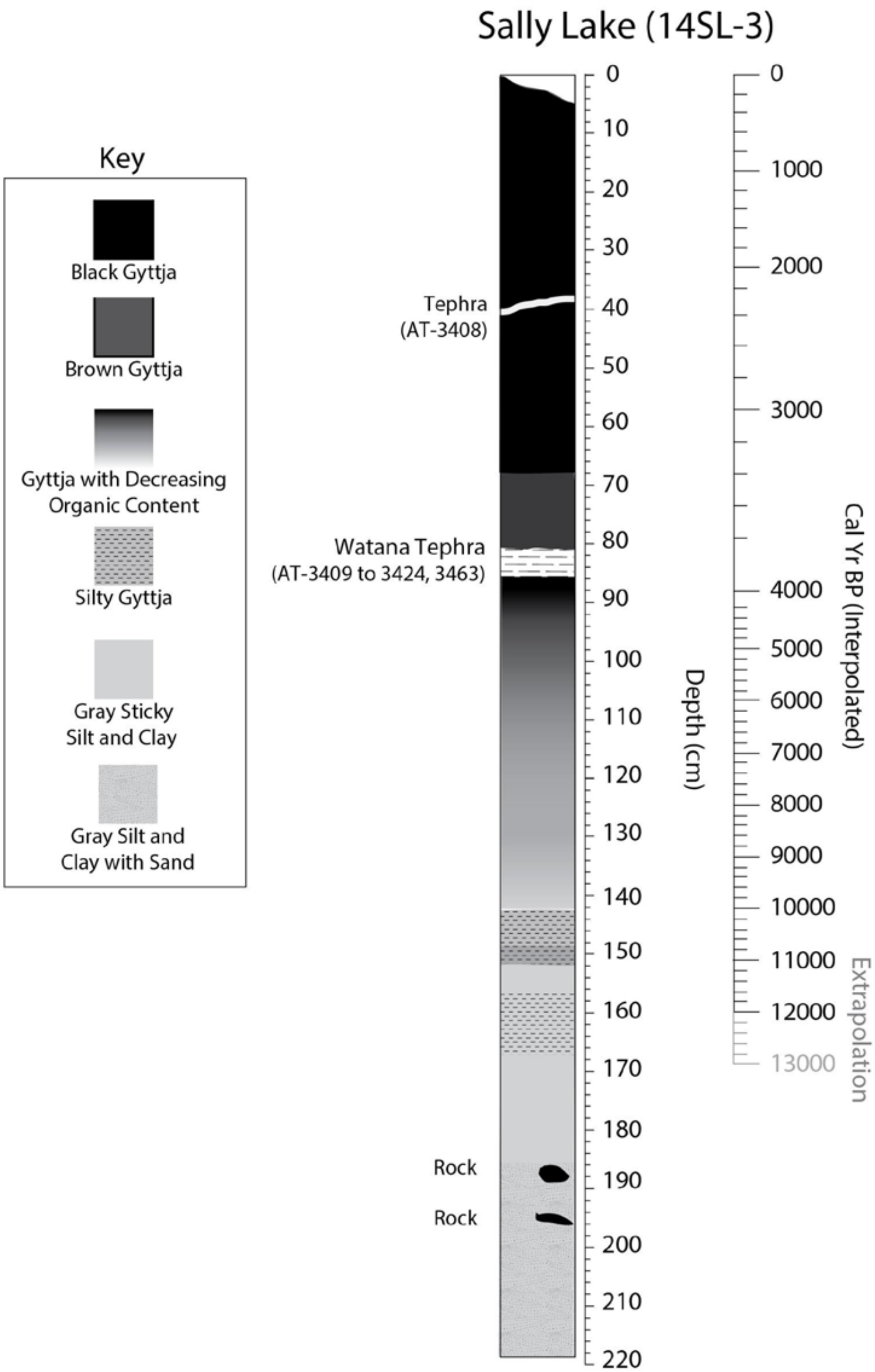

Figure 5.1.3-2: Sally Lake core stratigraphy.

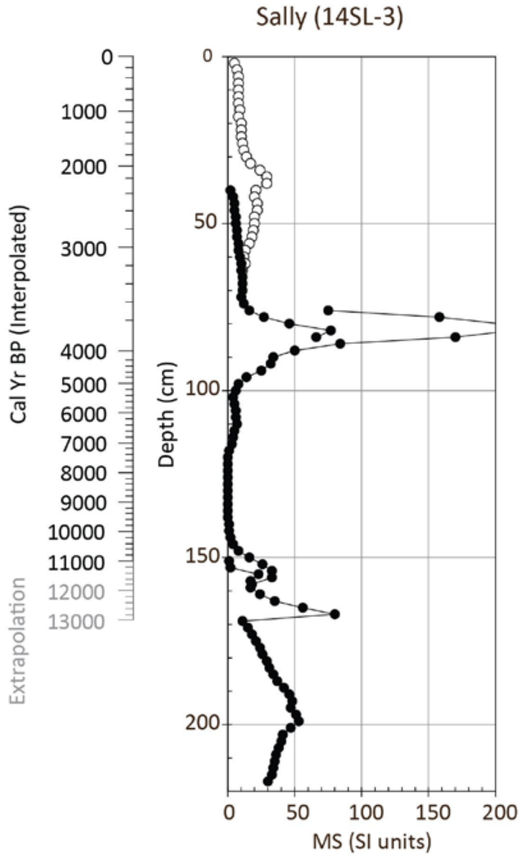

Figure 5.1.3-3: Sally Lake magnetic susceptibility.

The data show multiple overlapping drives for this core. As with Deadman and Clarence, open circles are data from the Bolivia core and closed circles are Livingstone cores. Because the Bolivia core is larger than the Livingstone cores, the MS values are higher.

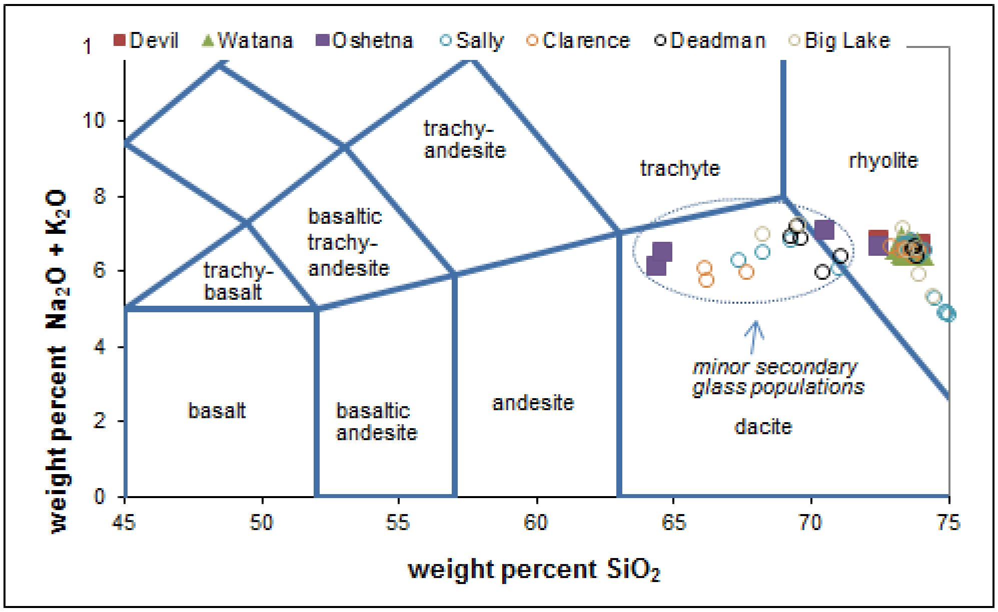

Figure 5.2-1: Total alkali silica diagram

Diagram shows the range of glass compositions for tephras found in lake cores (Sally, Clarence, Deadman, and Big Lakes) as well as reference tephras found in terrestrial sections in the Susitna River valley (Devil, Watana, and Oshetna). Circled analyses are minor secondary populations associated with primary rhyolite compositions.

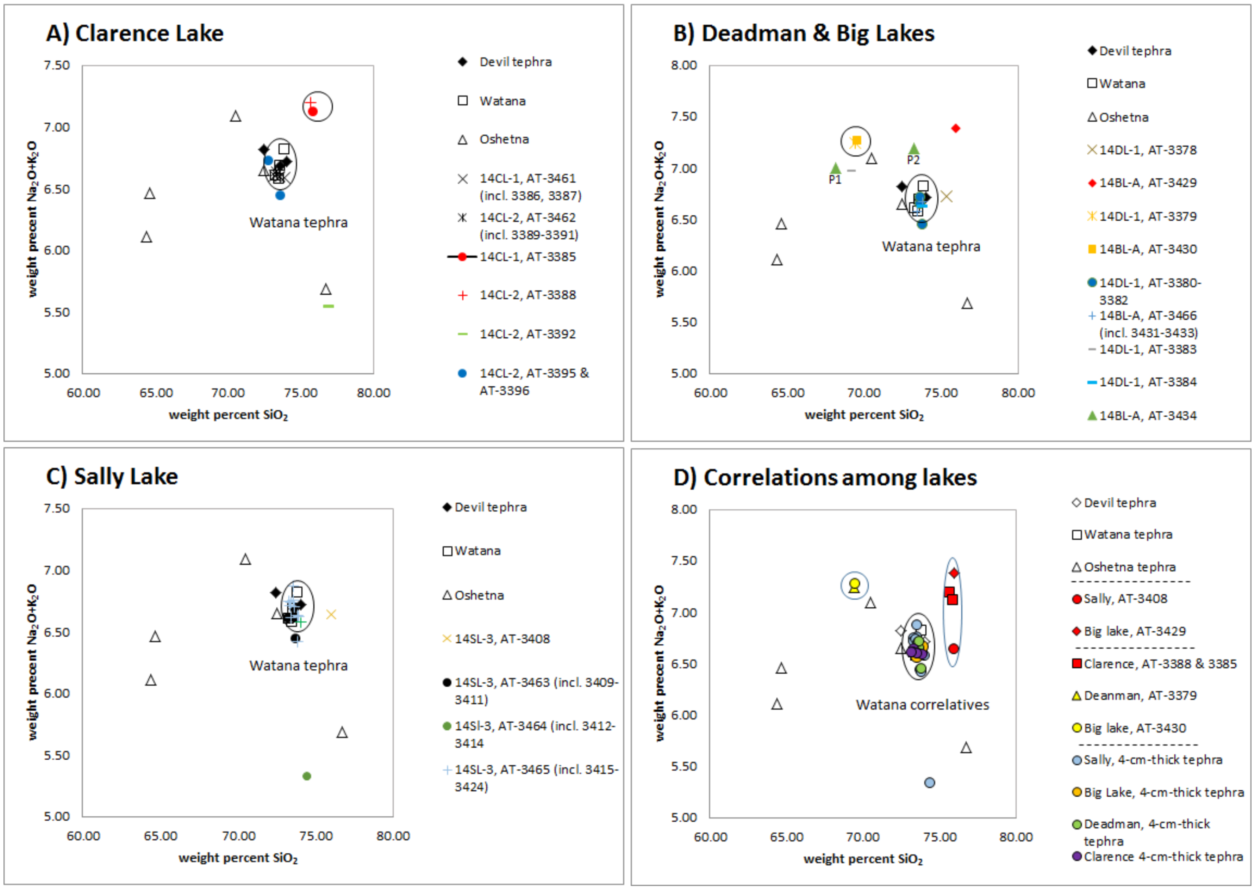

Figure 5.2.1-1: Total alkali silica diagrams.

Diagrams show glass compositions for tephras found in lake cores as well as reference tephras found in terrestrial sections in the Susitna River valley (Devil, Watana, and Oshetna). A) Shows tephra from both 14CL-1 and 14CL-2 cores from Clarence Lake. B) Shows tephra from Deadman and Big Lakes, which, at some point in the past, were probably one lake. C) Shows tephra from Sally Lake. D) Shows tephras that correlate across one or more lake basin. Circled tephras represent correlations. The encircled Watana tephra omits adjacent data points that are known to be stratigraphically different tephras. All correlations shown here are backed by both stratigraphic, age and geochemical similarity.

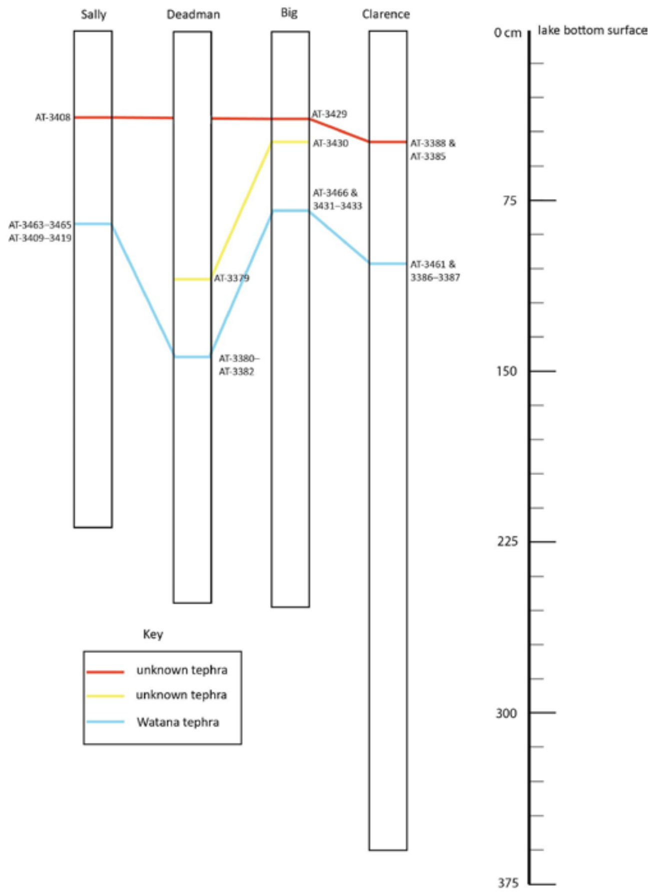

Figure 5.2.4-1: Fence diagram showing the tephra correlations between the cores.

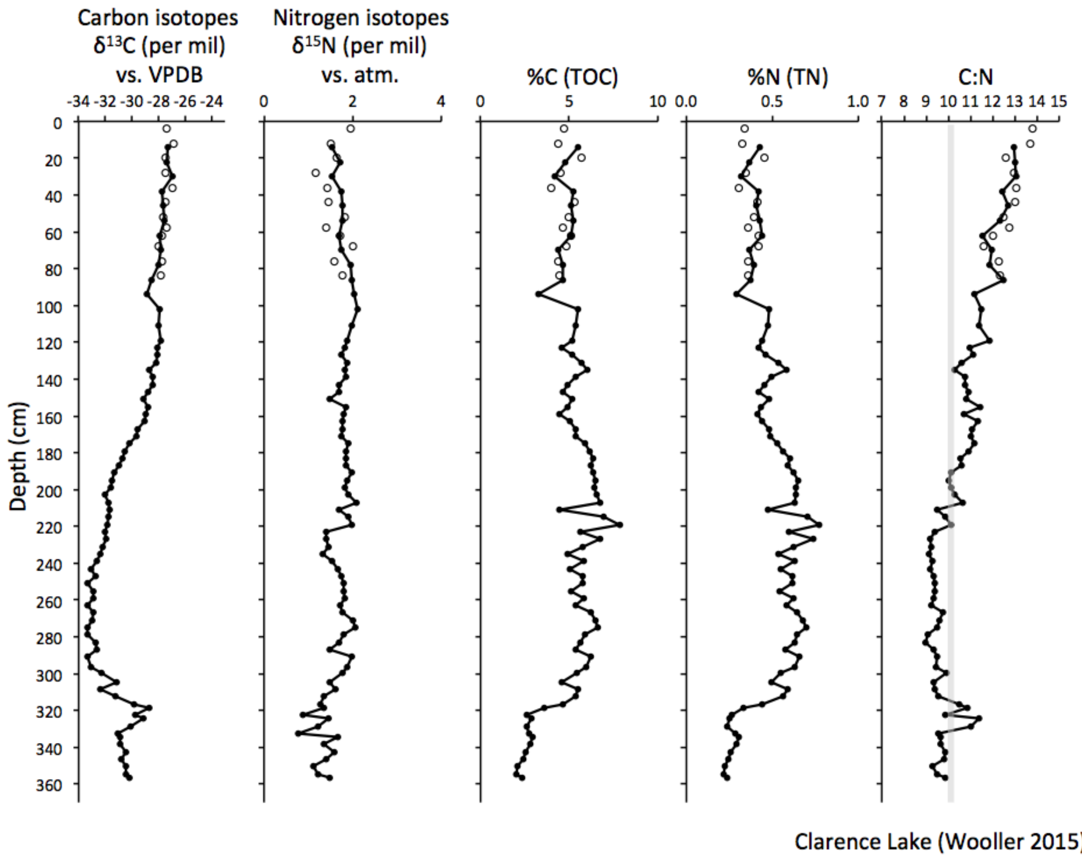

Figure 5.3.1-1: Clarence Lake stable carbon and nitrogen isotope data and elemental (C and N) percentages vs. depth.

Gray line in the C:N curve indicates the boundary between generally authochthonous organics (<10) and allochthonous organics (>10). Open circles are data from the overlapping Bolivia core.

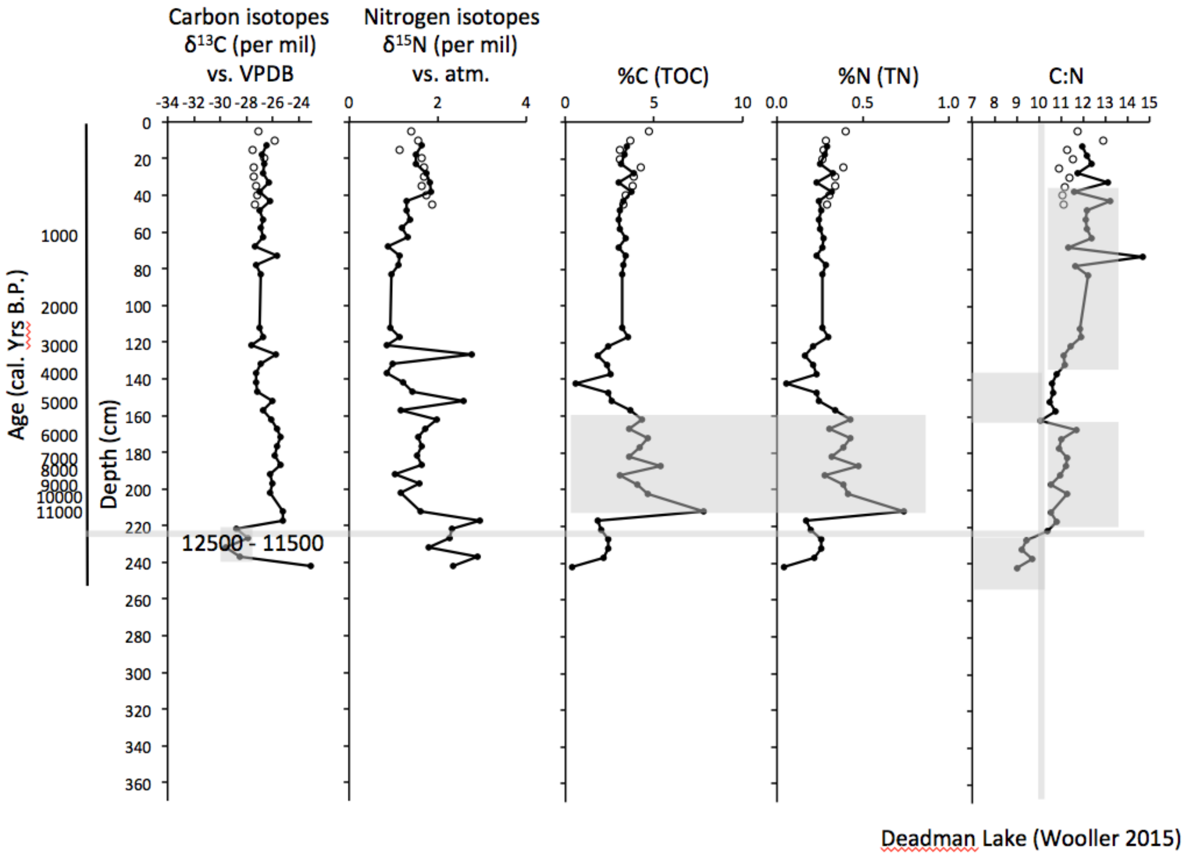

Figure 5.3.2-1: Deadman Lake stable carbon and nitrogen isotope data and elemental (C and N) percentages vs. depth (and a secondary age scale based on the chronologies for the core).

Some key features mentioned in the results text are highlighted in grey. Open circles are data from the overlapping Bolivia core.

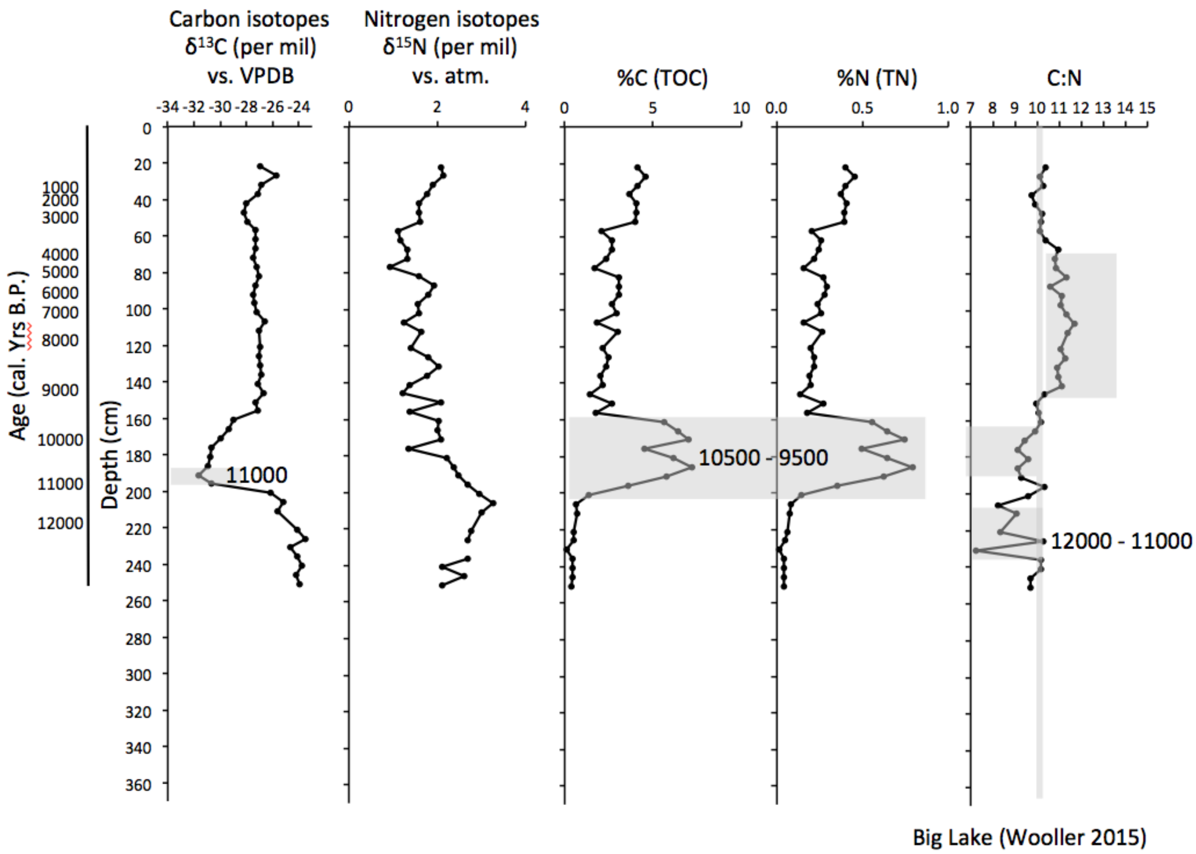

Figure 5.3.3-1: Big Lake stable carbon and nitrogen isotope data and elemental (C and N) percentages vs. depth (and a secondary age scale based on the chronologies for the core) for Big Lake.

Some key features mentioned in the results text are highlighted in grey.

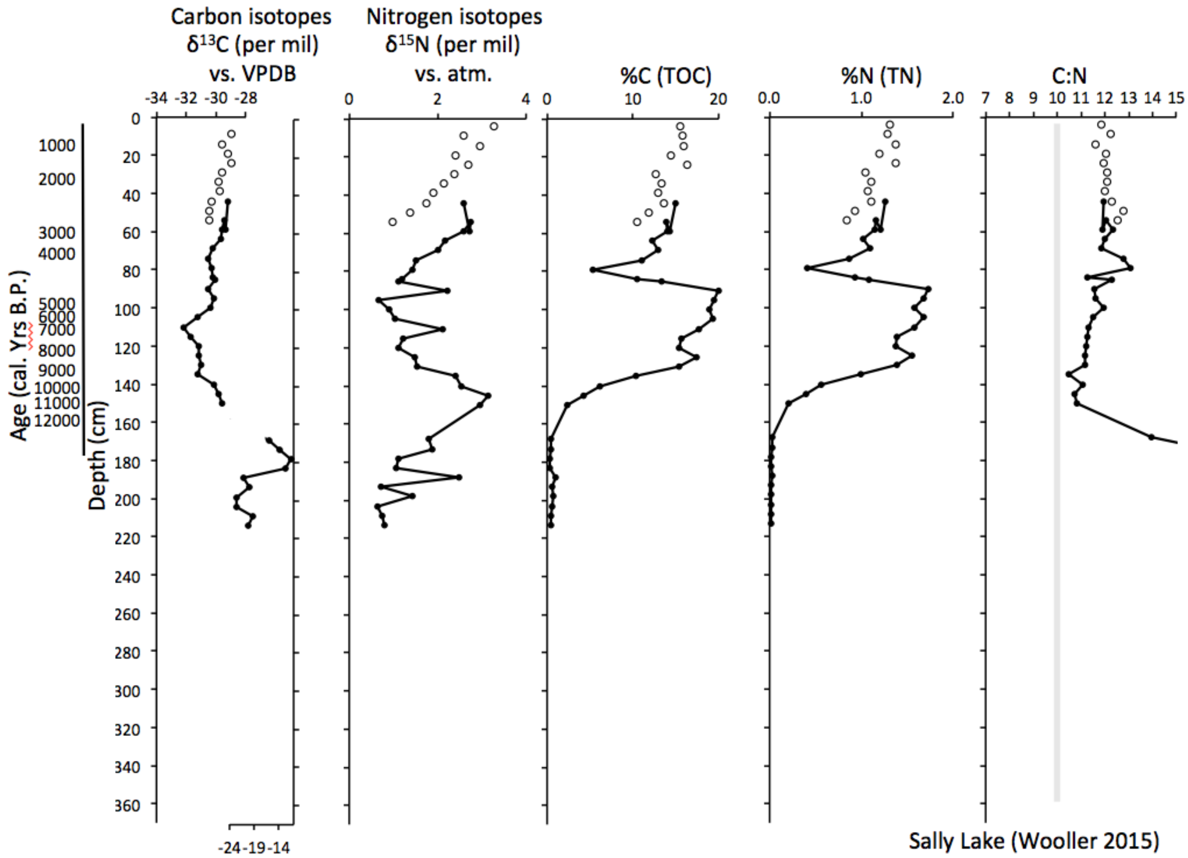

Figure 5.3.4-1: Sally Lake stable carbon and nitrogen isotope data and elemental (C and N) percentages vs. depth.

Gray line in the C:N curve indicates the boundary between generally authochthonous organics (<10) and allochthonous organics (>10). Open circles are data from the overlapping Bolivia core.

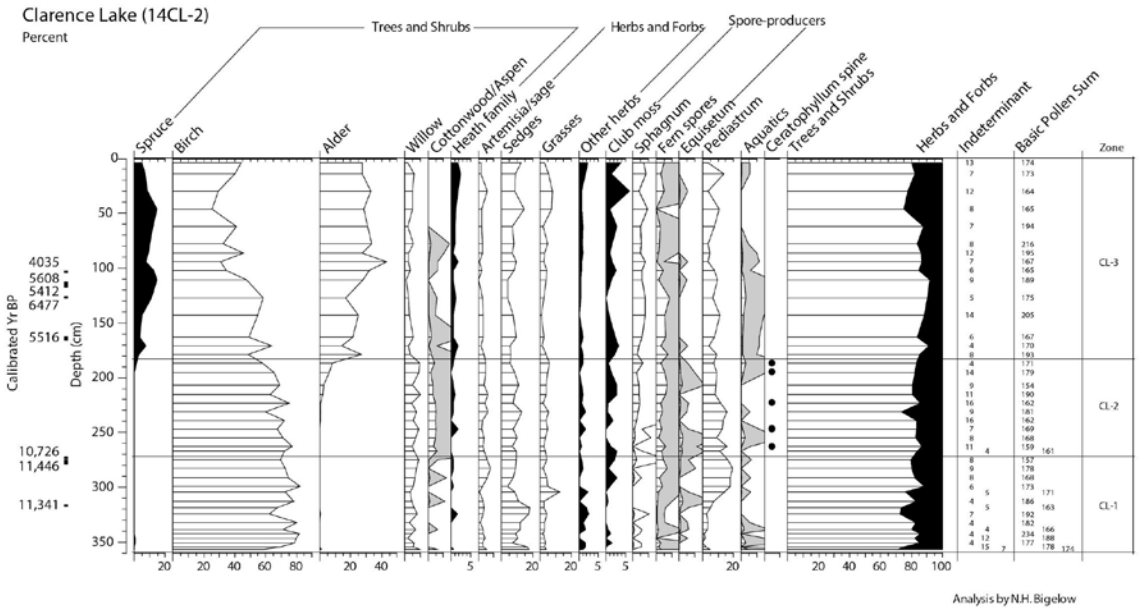

Figure 5.4.1-1: Clarence Lake pollen percentages.

Gray shading indicates 10X exaggeration.

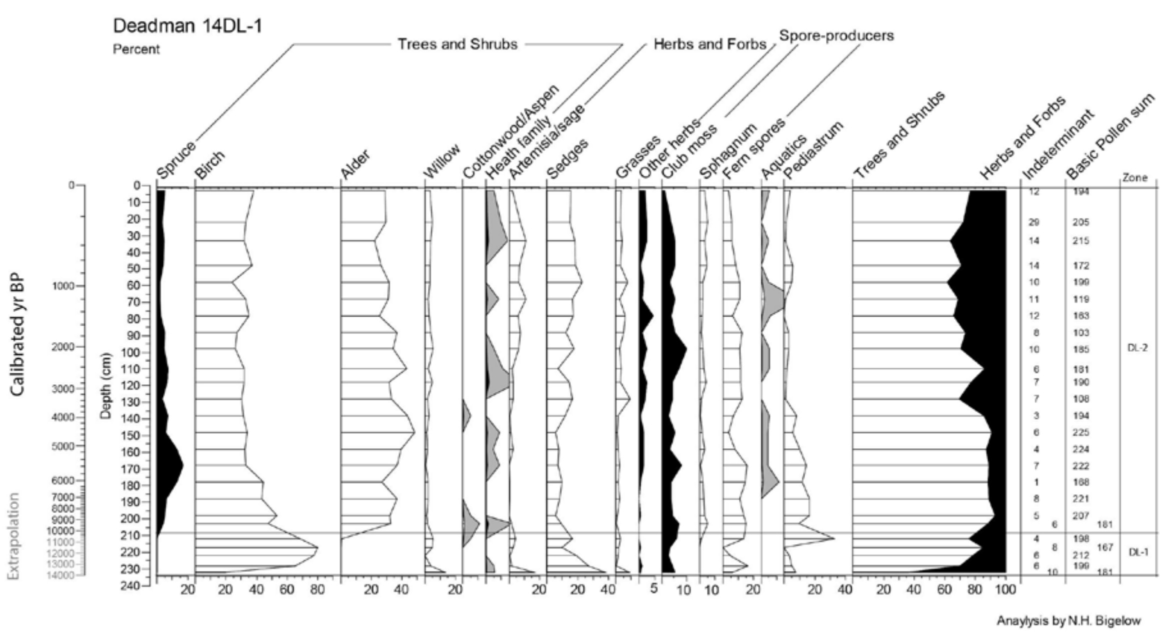

Figure 5.4.2-1: Deadman Lake pollen percentages.

Gray shading indicates 10X exaggeration.

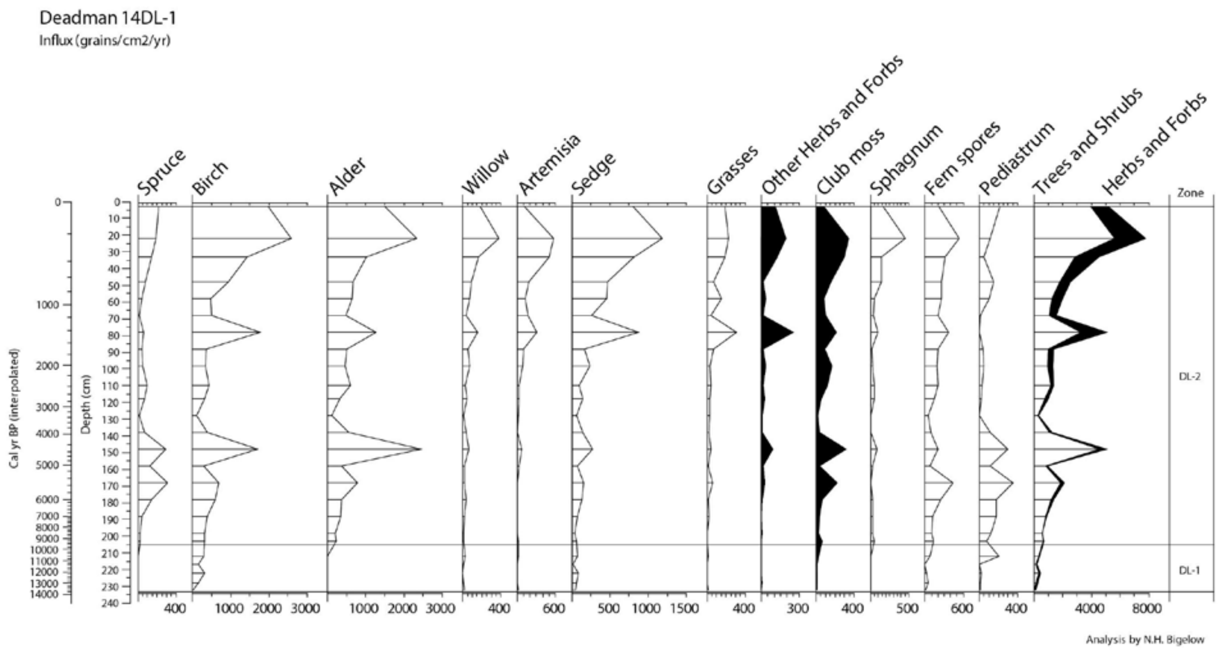

Figure 5.4.2.-2: Deadman Lake pollen influx.

Note changing X-axis scales.

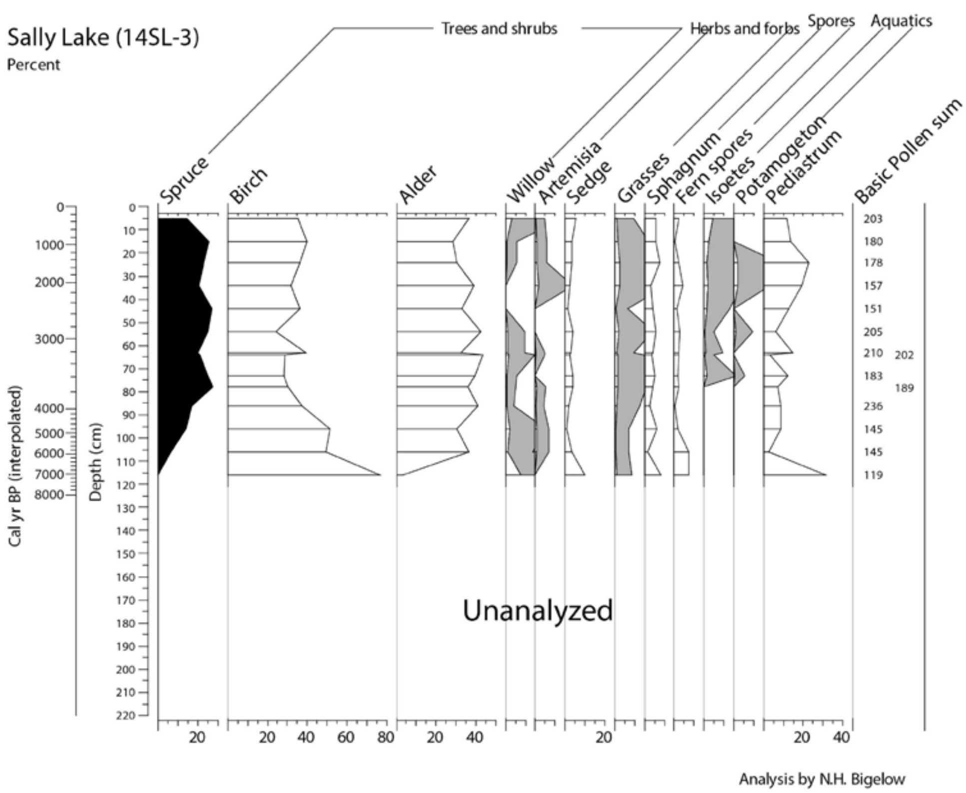

Figure 5.4.3-1: Sally Lake pollen percentages.

Gray shading indicates 10X exaggeration.

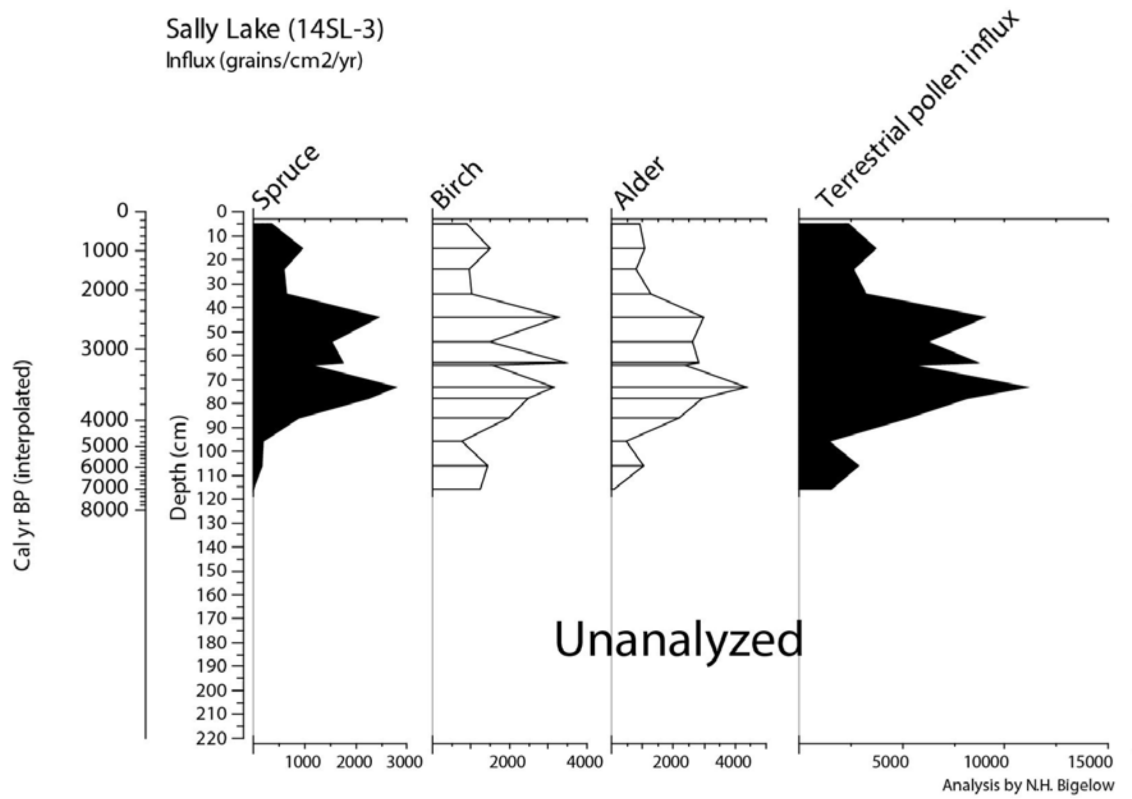

Figure 5.4.3-2: Sally Lake pollen influx. Note changing X-axis scales.

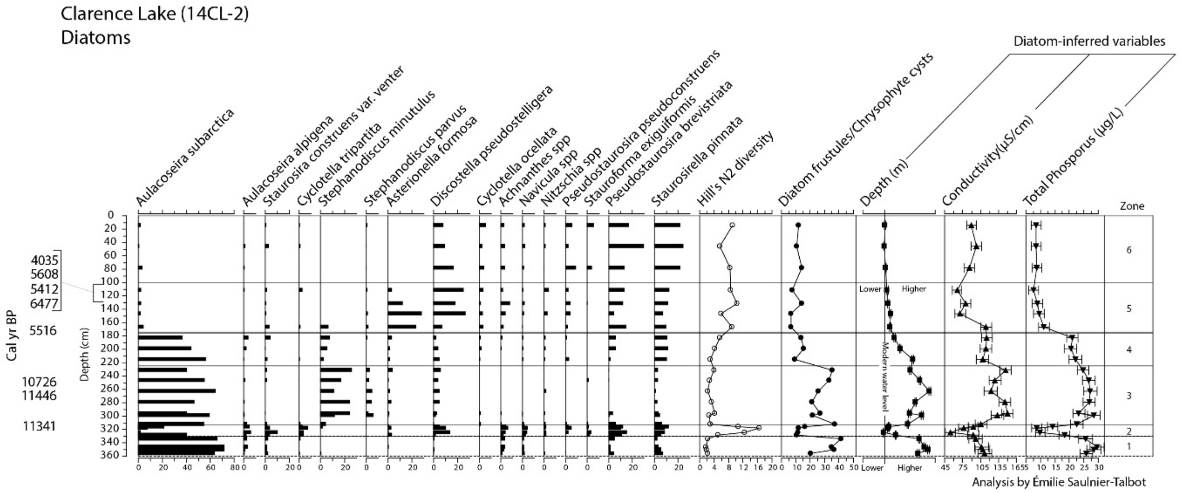

Figure 5.5-1: Relative abundances (%) of the most common diatom taxa preserved in the Clarence Lake sediment core.

Diatom diversity is expressed as Hill's N2. Diatom-inferred limnological variables including depth (m), conductivity (µS/cm) and total phosphorous (µg/L) are given for each downcore sample. The six zones at right are based on results of a stratigraphically constrained cluster analysis of downcore diatom assemblages (not shown).

ATTACHMENT 1, APPENDIX A: SUMMARY OF TEPHRA SAMPLE CHARACTERISTICS.

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
Clarence Lake (14CL-1)							
AT-3385	14CL-1	64–65	<4,035	0.1–0.3	white; very fine; discontinuous blobs; at same depth as AT–3388; clear contacts, broken boundary. Is this a primary deposit (Devil?) or reworked (Watana or Hayes?)?	bright white and dirty tan pumices – very small sample	should be the same as AT-3388
AT-3461	14CL-1	103–106	<4,035	4	4 cm thick (total); pinkish gray; 0.5 to 1 cm thick light pinkish gray fine lamination overlies 3 cm darker pinkish gray coarser bed; darker materials (organics? Lake mud?) may separate the fine and coarse fractions; clear contacts, smooth boundary.	bright white pumices and dirty golden pumices	sample is of entire 4 cm thick tephra in one sample; should be same as AT-3462
AT-3386	14CL-1	somewhere within 103–106	<4,035	1	light pinkish gray fine lamination from AT–3461.	abundant oxidized yellowish pumice and a few bright white pumice	sub-sample of AT-3461, should be the same as AT-3389
AT-3387	14CL-1	somewhere within 103–106	<4,035	3	darker pinkish gray coarser bed from AT–3461.	mostly bright white pumices, few dirty oxidized looking pumices	sub-sample of AT-3461, should be the same as AT-3390
AT-3399	14CL-1	133–134	4,035	0.1–0.2	white; very fine; broken (faulted?) but continuous; clear contacts; smooth boundary.	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size
AT-3400	14CL-1	163–164	<5,516	0.1	very fine; whitish lamination; discontinuous; clear contact, broken boundary. Reworked?	dirty tan pumices	no EPMA due to fine grain size
AT-3401	14CL-1	191–192	>5,516	1	very fine; whitish gray; discontinuous; clear contact, wavy boundary; "blob" shaped; possibly reworked?	dirty tan pumices	no EPMA due to fine grain size
AT-3402	14CL-1	213	>5,516	0.1	very fine; whitish gray; continuous; clear contact; slightly wavy boundary; upper lamination in a series of possible tephra laminations between 11 and 12 cm.	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3403	14CL-1	213.5	>5,516	0.1	very fine; whitish gray; discontinuous; clear contact; slightly wavy boundary; middle lamination in a series of possible tephra laminations between 11 and 12 cm.	dirty tan pumices	no EPMA due to fine grain size
AT-3404	14CL-1	214	>5,516b	0.1	very fine; whitish gray; continuous; clear contact; slightly wavy boundary; lower lamination(s) in a series of possible tephra laminations between 11 and 12 cm.	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size
AT-3405	14CL-1	242	>5,516	0.1–0.2	fine; continuous; whitish gray; clear contact; smooth boundary.	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size
AT-3406	14CL-1	322	>5,516	0.1	very fine; whitish gray; discontinuous; clear contacts; broken boundaries.	not enough material and too fine only <0.063 tan–cream powder	no EPMA due to fine grain size
Clarence Lake (14CL-2)							
AT-3388	14CL-2	49	<4,035	0.1–0.2	white; very fine; possibly discontinuous; as sampled, tephra became more continuous and coarser; at same depth as 14CL1–TEPHRA–1 very abrupt contacts, wavy boundary. Is this a primary deposit (Devil?) or reworked (Watana or Hayes?)?	abundant dirty tan pumices and some bright white pumice	should be same as AT-3385
AT-3462	14CL-2	94–97	4,035	4	4 cm thick (total); pinkish gray; 1 cm thick light pinkish gray fine lamination overlies 3 cm darker pinkish gray coarser bed; darker materials (organics? Lake mud?) may separate the fine and coarse fractions; clear contacts, smooth boundary.	mostly white pumices and some golden dirty pumices	sample is of entire 4 cm thick tephra in one sample; should be same as AT-3461
AT-3389	14CL-2	somewhere within 94–97	4,035	0.1	light pinkish gray fine lamination from AT–3462.	white and pale yellow pumices	sub-sample of AT-3462; should be same as AT-3386

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3390	14CL-2	somewhere within 94–97	4,035	1	darker pinkish gray coarser bed from AT–3462.	mostly bright white pumices, few pale yellow pumices	sub-sample of AT-3462; should be same as AT-3387
AT-3391	14CL-2	211.5	>5,516	0.1	whitish lamination (silt? Tephra?); very fine; continuous; clear contact, smooth boundary.	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size
AT-3392	14CL-2	224.5	>5,516	0.1	whitish lamination; very fine; continuous; clear contact, smooth boundary.	dirty tan pumices, look like clusters, may be difficult to probe	
AT-3393	14CL-2	226.5	>5,516	0.1	whitish lamination; very fine; continuous; clear contact, smooth boundary.	dirty tan pumices, some white pumices, some mixed	no EPMA due to fine grain size
AT-3394	14CL-2	238	>5,516	0.1	whitish lamination (silt? Tephra?); very fine; discontinuous; clear contact, broken boundary. Reworked?	not enough material and too fine only <0.063 mm tan powder	no EPMA due to fine grain size
AT-3395	14CL-2	289	<10,726	0.05–0.1	whitish lamination; very fine; discontinuous; clear contact, broken boundary. Reworked?	abundant dirty tan pumices	older tephra same source? Contamination while coring?
AT-3396	14CL-2	330.5	> 11,341	1	pinkish gray; very fine; clear contact, smooth boundary.	bimodal cream/white pumices	older tephra same source? Contamination while coring?
Deadman Lake (14DL-1)							
AT-3378	14DL-1	0–2	<52	1	light pinkish gray; fine; continuous; clear contacts, boundary slightly distorted by bolivia drive gel.	white chewed up pumices, crystals look etched, sugary	

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3379	14DL-1	115–116	2,555	0.05	discontinuous; fine; clear contact; wavy and slighty broken boundaries. Reworked?	golden subround pumices in 0.125 mm fraction; abundant diatoms; white sugary pumices in 0.063 mm fraction	
no sample	*14DL-1*	*142–146*	~4,039	*4*	*4 cm thick (total); laminated pinkish gray to gray; 1 cm thick gray coarse lamination (142–143 cm); 1 cm thick pinkish gray fine lamination (143–144 cm); 2 cm thick darker gray coarse bed (144–146 cm); clear contacts; smooth boundaries.*	*n/a*	sub-sampled only - no bulk sample of entire thickness
AT-3380	14DL-1	142–143	~4,039	1	gray coarse lamination; clear contact; smooth boundary within 4 cm thick tephra (143–146 cm)	bright white pumices, few irregular golden pumices; diatoms	sub-sample of AT-4 cm thick tephra (142-146 cm blf)
AT-3381	14DL-1	143–144	~4,039	1	pinkish gray fine lamination; clear contacts; smooth boundaries, within 4 cm thick tephra (143–146 cm)	white and pale yellow pumices	sub-sample of AT-4 cm thick tephra (142-146 cm blf)
AT-3382	14DL-1	144–146	~4,039	2	darker gray coarse bed; clear contacts; smooth boundaries.	mostly bright white and some dirty gold and dirty tan pumices	sub-sample of AT-4 cm thick tephra (142-146 cm blf)
AT-3383	14DL-1	153	4858-4541	0.2–0.3	pinkish gray; very fine; continuous; clear contact; smooth boundary, within 4 cm thick tephra (143–146 cm)	white pearly pumices, abundant diatoms, tan and white pumices	
AT-3384	14DL-1	237	14,802-14,051	0.2	pinkish blobs; discontinuous; clear to very abrupt contact; broken boundary. Reworked?	white pumices and 1 cream/tan pumice; 0.063 mm fraction has both tan and white pumice	

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
Big Lake (14BL-A)							
AT-3429	14BL-A	40	1,809	0.1–0.2	whitish cream colored; contacts mostly clear; contacts less clear towards the right side of the core (possibly distorted by drive); boundaries smooth, with some major undulations; very fine.	almost entirely composed on diatoms! With some cream pumices	
AT-3430	14BL-A	49	2,415	0.3–0.5	whitish gray; contacts blurry, not clear; boundaries are wavy (possibly reworked?); very fine.	almost entirely composed on diatoms with some dirty golden pumices in 0.125 mm and cream/tan pumices in 0.063 mm fractions	
AT-3466	14BL-A	80–84	5,041	4	Laminated tephra; 4 cm thick (total); fine cap layer at 80 cm; coarser fraction below at 80–82 cm, underlain by another 1 mm thick finer fraction; clear contacts; smooth boundaries.	white and pale yellow pumices	sample is of entire 4 cm thick tephra in one sample
AT-3431	14BL-A	80	5,041	0.1	Very fine lamination from AT–3466; whitish gray; homogeneous coloration; clear contact and smooth boundary.	white and pale yellow pumices	sub-sample of AT-3466
AT-3432	14BL-A	80	5,041	1	Coarse lamination from AT–3466; darker gray; colration is not homogeneous and is salt and pepper coloration (black and whiter particles); clear contact and smooth boundary.	white pumice	sub-sample of AT-3466
AT-3433	14BL-A	81	5,041	1	Very fine lamination from AT–3466; whitish gray; homogeneous coloration; clear contact and smooth boundary.	white pumice and dirty golden pumice (more in 0.063 mm than in 0.125 mm fraction)	sub-sample of AT-3466
AT-3434	14BL-A	96	6,228	0.1–0.2	whitish cream colored; discontiuous; contacts blurred; broken boundaries; possibly reworked?	cream and yellow chewed up pumices, crystals look etched, sugary	

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
Sally Lake (14SL-3)							
AT-3407	14SL-3	44–52	2,549	7	7 cm thick; fine; whitish gray; discontinuous; clear contacts; wavy boundary; "bolb" shaped. Sample taken form the center of the blob.	bright white pumices	disturbed sed/water interface - use bolivia 2
AT-3408	14SL-3	39–41	2,365	0.5	0.5 cm thick; fine; whitish gray; mostly continuous; abrupt contacts; smooth boundary.	bright white pumices	bolivia 2 core
AT-3463	14SL-3	80–85	3,840	4–5	Laminated tephra; 4–5 cm thick (total); 3 distinct textural changes; clear contact; smooth boundary.	white and pale yellow pumices	sample is of entire 4-5 cm thick tephra
AT-3409	14SL-3	80	3,840	0.5	Very fine lamination from AT–3463; whitish gray; homogeneous coloration; clear contact; smooth boundary.	cream and pale yellow pumices, brown clusters in 0.063 fraction	sub-sample of AT-3463
AT-3410	14SL-3	80.5–83	3,840	1.5	Coarser lamination from AT–3463; darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); abrupt contact; smooth boundary.	cream and pale yellow pumices	sub-sample of AT-3463
AT-3411	14SL-3	83–85	3,840	2	Fine lamination from AT–3463; whitish gray; homogeneous coloration; clear contact; smooth boundary.	cream and pale yellow pumices	sub-sample of AT-3463
AT-3464	14SL-3	80–84	3,840	4–5	Laminated tephra; 4–5 cm thick (total); 3 distinct textural changes; clear contact; smooth boundary.	white and pale yellow pumices	sample is of entire 4-5 cm thick tephra
AT-3412	14SL-3	80–80.5	3,840	0.5	Very fine lamination from AT–3464; brownish gray; homogeneous coloration; clear contact; wavy boundary.	dirty tan and white pumices	sub-sample of AT-3464

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3413	14SL-3	80.5–82	3,840	1.5	Coarser lamination from AT–3464; darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); clear contact; smooth boundary.	mostly bright white and a few pale yellow pumices	sub-sample of AT-3464
AT-3414	14SL-3	82–84	3,840	2	Fine lamination from AT–3464; whitish gray; homogeneous coloration; clear contact; smooth boundary. Basal contact is end of core and may continue into Drive 5 (starting at AT–3465).	white and pale yellow pumices	sub-sample of AT-3464
AT-3465	14SL-3	76–85.5	3,840	9.5	Laminated tephra; 9.5 cm thick (total); textural changes between finer and coarser particles in laminations; clear contact; wavy boundary.	white and pale yellow pumices	sample is of entire 9.5 cm thick tephra
AT-3415	14SL-3	76–77	3,840	1	very fine lamination of AT–3465; brownish gray; clear contact; smooth boundary.	dirty tan pumices	subsample of AT-3465
AT-3416	14SL-3	77–78	3,840	1	Coarser fraction from AT–3465; 4 cm (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); some laminations of finer particles within coarser bed; clear contact; smooth boundary.	white and pale yellow pumices	subsample of AT-3465
AT-3417	14SL-3	78–79	3,840	1	Coarser bed from AT–3465; 4 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); some wavy laminations of finer particles within coarser bed; abrupt contact and discontinuous boundary due to crack in part of the sediments at that depth of the drive.	white and pale yellow pumices	subsample of AT-3465

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3418	14SL-3	79–80	3,840	1	Coarser bed between 2–6 cm from AT–3465; 4 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); some wavy laminations of finer particles within coarser bed; abrupt contact and discontinuous boundary due to crack in part of the sediments at that depth of the drive.	white and pale yellow pumices	subsample of AT-3465
AT-3419	14SL-3	80–81	3,840	1	Coarser bed between 2–6 cm from AT–3465; 4 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); some wavy laminations of finer particles within coarser bed; abrupt contact and discontinuous boundary due to crack in part of the sediments at that depth of the drive.	white and pale yellow pumices	subsample of AT-3465
AT-3420	14SL-3	81–82	3,840	1	Coarser bed between 2–6 cm from AT–3465; 4 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); some wavy laminations of finer particles within coarser bed; abrupt contact and discontinuous boundary due to crack in part of the sediments at that depth of the drive.	mostly white and fewer pale yellow pumices	subsample of AT-3465
AT-3421	14SL-3	82–83	3,840	1	Finer bed between 6–10 cm from AT–3465; 3.5 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); clear contact, wavy boundary.	white pumices	subsample of AT-3465
AT-3422	14SL-3	83–84	–	1	Finer bed between 6–10 cm from AT–3465; 3.5 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); clear contact, wavy boundary.	white pumices	subsample of AT-3465

AT-No.[a]	Core	Depth below sediment/water interface (cm)	Estimated Age, cal yr BP[b]	Thickness, cm	Core Description (UAF)	Tephra Characteristics (USGS/AVO)	Notes
AT-3423	14SL-3	84–85	3,840	1	Finer bed between 6–10 cm from AT–3465; 3.5 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); clear contact, wavy boundary.	white pumice and brown organics (?)	subsample of AT-3465
AT-3424	14SL-3	85–86	3,840	1	Finer bed between 6–10 cm from AT–3465; 3.5 cm thick (total); darker whitish gray; heterogeneous coloration (salt and pepper coloration of black and white particles); clear contact, wavy boundary.	white pumices and dirty brown organics or pumices (?) – no brown material in 0.063 mm fraction	subsample of AT-3465

[a]Alaska Tephra Laboratory and Data Center identification number (AT #)
Abbreviations: blf--below lake floor; cal--calibrated years before present; UAF--University of Alaska Fairbanks; USGS--U.S. Geological Survey; AVO--Alaska Volcano Observatory; No.--number, EMPA--electron microprobe analyses.
[b]Estimated ages for Clarence lake tephra are based on individual radiocarbon ages; estimated ages for Sally, Big, and Deadman Lakes are modeled ages.

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