AN INTERDISCIPLINARY APPROACH TO REFINING THE ARCHAEOLOGICAL AND GEOMORPHOLOGICAL RECORD OF THE WALKER LAKE BASIN, NEVADA

A Dissertation

by

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ABSTRACT

This dissertation presents new data to reevaluate the Holocene archaeological and geomorphological record in the Walker Lake Basin of western Nevada. The data discussed were collected using a suite of methodological approaches both above and below the contemporary Walker Lake waterline, which is prone to climate related fluctuations. My analysis provides updates to the historical lake curve and the basin's environmental history and discusses patterns of precontact land use.

I present this research across three articles. In the first article, I highlight the technical approaches used to collect the new data. Terrestrial archaeological surveys focused on the modern Walker River channel, Walker River's abandoned channels, and relict Walker Lake shorelines. Underwater research included sub-bottom remote sensing survey and test excavations within Walker Lake to identify preserved features, stratigraphy, and archaeology. As a result, I identified 38 new archaeological sites on land and preserved fluvial and lacustrine features under the modern lake.

In the second article, I focus on the geomorphological history of Walker Lake, building on previous research in the basin. I combine details from river cutbanks, results from sub-bottom survey, materials from underwater excavation and coring, radiocarbon dates, and tephra samples. With these data I reevaluate the previous lake-level curve, identifying new elevations of lake lowstands elevations, correlate stratigraphic records to volcanic events, and theorize about local environmental changes.

The final article analyzes the spatial distribution of archaeological sites and artifacts within the Walker Lake basin, addressing questions about human adaptations relative to the landscape. I combine newly recorded archaeological sites with previous archaeological efforts to statistically analyze the spatial distribution of materials and sites relative to age components, landscape features, and elevation ranges. These analyses show significant relationships between artifact classes, site types, activities, and site ages relative to the landscape.

This work contributes to both the environmental history and the archaeological record of the Walker Lake basin. By taking a regional approach, my research is invaluable for providing a broad conception of land use and adaptation across the Great Basin and for understanding the connection between behavioral adaptations and environmental change throughout human history.

DEDICATION

To my parents: Terry, Dave, Mary, and Neil. Thank you for your love, support, and guidance.

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I want to thank the Nevada Bureau of Land Management for facilitating access to the Walker Lake basin and to their archaeological records. I want to express special thanks to State archaeologist Bryan Hockett and Carson City District Archaeologist Jason Wright for their help with permitting and access. My fieldwork would not have been possible without the assistance of multiple students from the Texas A&M University Department of Anthropology. I want to thank Adam Burke, Jacob Frisbee, Kristi Hinton, Danielle Lynch, Jordan Pratt, and Morgan Smith for their help. Additionally, I am grateful for the field assistance of A.J. Van Slyke and Hunter Whitehead from the University of West Florida, and Loren Christian and Trevor Hough from East Carolina University.

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The AMS radiocarbon dating presented and discussed in Sections 2 and 3 was performed by the Penn State Radiocarbon Laboratory, managed by Dr. Brendan Culleton. Maggie Davis acted as the research technician for the radiocarbon dating process. Tephra analyses presented in Section 3 were performed by Dr. Stephen Kuehn at the Electron Microprobe Facility and Tephra Laboratory at Concord University. The previously recorded archaeological sites in the Walker Lake Basin discussed in Sections 2 and 4 were provided by the Nevada BLM Carson City District Office. The author identified and collected pertinent site records from this facility. The fieldwork discussed throughout this dissertation was collected with the assistance of a team of professional and student volunteers including Dr. Jessi Halligan, Dr. Morgan Smith, Dr. Sunshine Thomas, Adam Burke, Lauren Christian, Jacob Frisbee, Kristi Hinton, Trevor Hough, Danielle Lynch, Jordan Pratt, A.J. Van Slyke, and Hunter Whitehead. Some of the artifacts discussed in Section 4 were counted and organized by Angela Martillotti, a student in the Department of Anthropology at Texas A&M.

All other work conducted for the dissertation was completed independently by the author.

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NOMENCLATURE

BF	Below aluminum frame
BP	Years before present
BS	Below sediment surface
^{14}C	Radiocarbon years before present
cal BP	Calendar years before present
masl	Meters above sea level
MCA	Medieval Climatic Anomaly
TB	Test Block
WLB	Walker Lake basin

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1. INTRODUCTION

Archaeological and associated geological research around dry pluvial lakes and marshes has been a continuous focus in the Great Basin. This work has provided transformational contributions to these fields and environmentally related subfields (Adams 2007; Adams and Rhodes 2019a; Adams and Wesnousky 1998; Antevs 1948; Benson et al. 1990; Bettinger and Baumhoff 1982, 1983; Broughton and Grayson 1993; Graf and Schmitt 2007; Grayson 2011; Jennings 1978; Madsen et al. 2015; Oviatt et al. 2003; Steward 1972; Thomas 1983; Thomas et al. 1988). Archaeological resources from pluvial lake settings have allowed identification of varied human behavioral adaptations to marsh, lacustrine, and desert environments (Adams et al. 2008; Duke and Young 2007; Goebel et al. 2011; Graf 2001; Smith 2007, 2010; Thomas et al. 1988). In the Great Basin, this research is often associated with surface sites on lacustrine landforms surrounding dry lake playas. Unfortunately, such sites regularly represent a palimpsest of activities from an indeterminate number of occupations for an indeterminate amount of time (Goebel 2007; Grayson 2011; Grayson and Cannon 1999; Jones et al. 2003; Smith 2010). At the same time, research into regional climates, changing lake levels, and environmental shifts have consistently informed the archaeological record (Adams and Rhodes 2019b; Benson et al. 1990; Louderback and Rhode 2009). This work allows archaeologists to better understand the context of the archaeological record and interpret human adaptations and behaviors at both local and regional scales (Adams et al. 2008; Duke and King 2014; Graf 2001; Grayson 2011).

Despite the consistent and regular work addressing archaeology and the environment, buried landscapes submerged under perennial lakes have generally remained an untapped resource for expanding on, and refining, Great Basin archaeology and environmental history. This dissertation addresses this shortcoming by applying an interdisciplinary approach to investigating the archaeological and geomorphological records of the Walker Lake basin (WLB) in western Nevada. Here I detail investigations both above and below the Walker Lake waterline, focusing on extant fluvial and lacustrine features within the basin. I demonstrate the value of this approach by providing a detailed, high resolution update to our understanding of the late Holocene geomorphological and environmental record of the WLB. I then describe analyses concerning human landscape use and technological adaptations through time and across the region. The themes directing this research are described below.

1.1. Research Themes

The topics and themes directing my work are associated with geological, environmental, and archaeological questions. While my research is fundamentally archaeological in nature, understanding the relationship between archaeology and geologic, climatic, and environmental history are essential for successfully interpreting the archaeological record (Stafford 1995; Waters 1992). My dissertation acknowledges the relationship between archaeology and earth sciences by addressing themes from both to develop an integrated research approach.

1.1.1. Great Basin Archaeology and the Value of Underwater Approaches

The archaeological record in the Great Basin, dominated by surface lithic scatters, has necessitated development of robust theoretical and methodological perspectives. Regional site formation processes limit sediment deposition and site burial in most open-air contexts (Grayson 2011). Therefore, surface survey has been highly productive, with thousands of surface lithic scatters recorded. Unfortunately, these sites usually represent palimpsests of multiple activities, time periods, and technological traditions (Beck and Jones 1997; Grayson 2011; Grayson and Cannon 1999), presenting a limited and blurry view of technological organization and land-use strategies.

To combat this limitation, archaeologists try to find buried, well-stratified sites that preserve lithics, ecofacts, and features in association with datable materials. Researchers have turned to caves and rockshelters for such materials (Graf and Schmitt 2007; Grayson 2011). While these settings provide invaluable information about the precontact Great Basin, they only represent one site type in the region. Archaeologists have also used the spatial distribution of surface sites to determine their chronological context. Adams et al. (2008) used beach ridges and pluvial lake chronologies to estimate relative dates for sites in the Winnemucca Dry Lake and Black Rock Desert basins. Others have used a similar approach to date sites along the Old River Bed (Duke and Young 2007; Madsen et al. 2015; Schmitt et al. 2007). Such attempts to provide relative ages for surface sites are important; however, ultimately they only provide *terminus post quem* dates, and assemblages are still subject to the palimpsest issue. To develop a more complete understanding of human adaptations and behavior, we must find buried, well-stratified, open-air sites. The very few buried sites in these contexts have already provided invaluable information (e.g., Davis and Schweger 2004; Huckleberry et al. 2001; Raven 1990; Smith et al. 2020; Wriston 2003; Zeanah et al. 1995). In the arid Great Basin, humans would have consistently targeted water resources, and lakes preserve buried sediment typically deposited in low-energy environments. Therefore, lakes are a good place to search for buried, open-air archaeological sites and information about local environmental history (Adams et al. 2008; Bedwell 1973; Duke and Young 2007; Goebel et al. 2011; Grayson 2011; Jones and Beck 1999; Mazurkevich et al. 2010; Sears et al. 1994; Thomas et al. 1988; Tuohy 1988).

Low-energy deposition in lakes is observable as silt that forms playas across the region. Locations that humans exploited below modern lake levels have excellent potential for rapid burial under these low-energy deposits once waters rise and submerge them (Puckett 2014; Tuohy 1988; Waters 1992). While the potential for site and feature destruction due to wave action and shoreline lapping is present, the short fetch of Great Basin lakes during low-water levels allows for the limited redistribution of only small particles (Davidson-Arnott 2010). Materials preserved in these deposits are best accessed by underwater investigations. Through reconnaissance surveys, sub-bottom remote sensing, and environmental reconstruction, archaeologists and geologists can develop a submerged testing program to investigate drowned locations with the highest potential for identifying preserved sites, geomorphological features, and environmental proxies.

Across North America, archaeological investigations of submerged landscapes have revealed remarkably preserved artifacts and ecofacts, transforming our knowledge of many regions and time periods (Faught 2004; Fedje et al. 2011; Halligan et al. 2016; Mackie et al. 2011; O'Shea and Meadows 2009; Webb 2006). Past and present investigations have shown that the potential for preservation in submerged contexts in the Great Basin is excellent. When perennial lakes have historically reached record lows, well-preserved materials are often recovered. For example, at Pyramid Lake the Wizard’s Beach remains provide one of only a few early human skeletons in North America (Dansie 1997; Jantz and Owsley 2001). Osseous, ivory, and antler rods as well as perishable textiles dated to the late Pleistocene and early Holocene were found eroding from Pyramid Lake sediments associated with the low, early Holocene lake (Dansie and Jerrems 2004; Rendall 1966; Tuohy 1988). Downcutting of lacustrine sediments across Stillwater Marsh, Lake Malheur, and Great Salt Lake during the late 1980s uncovered hundreds of well-preserved human and faunal remains that were drowned and buried by high lake levels (Hemphill and Larsen 1999). Such finds demonstrate the potential to discover exceptionally well-preserved materials in underwater contexts. Despite the high preservation potential, no consistent underwater work has been done in the Great Basin. Difficulty and cost of access have been the primary limitations for investigating these contexts, but methodological and technological advances now make underwater research easier and cheaper (Halligan 2012; Webb 2006), allowing for a broader research approach in the Walker Lake basin that considers both the terrestrial and underwater landscapes.

1.1.2. Geomorphology and Environmental Research in the Walker Lake Basin

Paleoclimatic and environmental history research in the WLB has generally focused on changing lake levels and the conclusions that can be drawn from the lake at a given period. Research and investigations of the lake have occurred since the nineteenth century (Adams 2007; Harding 1965; Russel 1885), eventually producing a history of the lake from ~50,000 BP (Benson 1988; Benson et al. 1990; Bradbury et al. 1989; Newton and Grossman 1988). Early efforts focused on recording lake conditions and identifying and estimating the historic lake highstand (Adams 2007; Harding 1965; Russel 1885). These efforts were expanded by Larry Benson and the USGS in the 1970s and 1980s when multiple cores were collected from the lake along with tufa-outcrop samples. This work produced multiple papers focused on the geochemical and fossil evidence, which ultimately drew conflicting results (Benson 1988; Benson and Thompson 1987; Bradbury et al. 1989; Newton and Grossman 1988). Studies focusing on tufas and geochemistry (Benson 1988; Benson and Thompson 1987; Newton and Grossman 1988) argued the lake was high until 43,500 cal BP when it desiccated to a saline lake or dry playa until ~17,000 cal BP. It then rebounded, connecting to Pleistocene Lake Lahontan. Lake levels once again began falling by 14,700 cal BP and the lake remained low before rebounding by ~5,500 cal BP. Afterwards, lake levels fell from ~2,800 to 2,000 cal BP, then rebounded and remained high until the modern lake recession began. Conversely, Bradbury et al. (1989) focused on the diatom, crustacean, and pollen records in the cores, arguing the lake did not desiccate until ~29,000 cal BP and was completely dry from ~18,000 to ~5,500 cal BP. It fell again from 2,500 to 2,000 cal BP. Research by Adams and Wesnousky (1998) supported Benson and Thompsons' (1987) late Pleistocene timeline, establishing Walker Lake was connected to Lake Lahontan at ~15,700 cal BP.

Subsequent research has largely focused on the late Holocene record of Walker Lake, using a suite of different proxy records. Adams (2007) and Adams and Rhodes (2019b) focused on cutbanks along the Walker River and preserved lake features, producing the current late Holocene lake curve. This record identifies a high lake beginning ~5,000 cal BP, with subsequent lowstands dating to ~2,000, ~1,000, and 300 cal BP. Yuan et al. (2004, 2006a, 2006b) studied $\delta^{18}O$ isotope records from sediments in the WLB, generally establishing the same lake chronology as Adams (2007) and Adams and Rhodes (2019b). The only exception was Yuan et al.'s (2006b) placed the ~2,000 cal BP desiccation earlier. Their research indicates this recession began by 2,700 cal BP and the lowstand occurred at 2,400 cal.

Other researchers have studied other elements of the basin to investigate the lake curve and past environmental conditions. Berelson et al. (2009) used carbonate-associated sulfate to estimate lake level, producing results similar to Yuan et al. (2006b). Petryshyn et al. (2012) studied stromatolite fossils in local tufa deposits to estimate local environmental conditions along with the lake curve, arguing that El Niño cycles may have controlled rates of tufa formation. Hatchet et al. (2015) measured drowned stumps in the West Walker River to estimate drought conditions that may have controlled lake level during the late Holocene. Adams and Rhodes (2019b) further modeled past Walker River levels to estimate whether climate or river avulsion controlled levels in Walker

Lake. They concluded that the lake level was almost exclusively controlled by river avulsion into and out of the WLB via the Adrian Gap, a valley north of the Walker Basin that runs north-south between Mason Valley and the Carson River drainage system. Their results suggest only the 2,000 cal BP desiccation appeared to have a climatic component. Beutel et al. (2001) studied the more recent effects of Walker Lake desiccation, predicting mass fish die-offs and generally lower organic productivity, which have since come to pass. Finally, Lopes and Smith (2007) produced a bathymetric map of the lake floor, and Lopes and Allander (2009) studied the lake's water regime, determining that the lake has reached relative equilibrium and should not continue to fall.

These studies demonstrate a robust record of work in the WLB. Nonetheless, additional research can clarify the environmental and lake-history record. Of note, large portions of the sediment in cores recovered by Benson (1988) were mixed, unable to provide information about the past environmental record. This is especially true in the sediments dating from ~15,000-5,000 cal BP. Additionally, many of the dates recovered for the WLB record are on tufa samples or bulk inorganic carbon. Tufas are open systems that absorb carbon from their environment and the material dated from bulk samples is unknown. As a result, ages obtained from these materials have increased potential for inaccuracy and/or chronological uncertainty (MacDonald et al. 1991; Srdoč et al. 1986). Information about past environmental productivity in the valley is largely dependent on small lake fauna and does not consider fish populations, floral productivity, or pollen records. Finally, the information about the timing and elevation of lake lowstands during the Holocene is dependent on upland records, lake-level estimates, and/or drowned sediments dated using bulk carbon. My research addresses issues associated with paleoecological materials, dating materials, and upland records by investigating features both above and below the contemporary waterline to refine the lake chronology and investigate past environmental productivity.

1.1.3. Lithic Technological Organization and Mobility

Archaeological research into the technical organization and mobility of past societies is a regular approach for studying human adaptations and behavior. This research is founded on models that place foragers along a continuum between residentially-organized, highly-mobile populations and logistically-organized, less-mobile populations (Binford 1980, 1991, 2001; Graf 2010; Kelly 1995; Kuhn 1995). Residentially-organized groups are expected to provision individuals with a small number of light and effective tools made on high-quality materials. The high-mobility of these groups allows them to reduce risks of material shortfalls by acquiring lithic raw material when it is encountered while foraging. Populations engaged in this strategy should increase distance between toolstone sources. They make extended use of the tools and material they have, so they tend to be associated with tools that are extensively resharpened and reused. Because populations adapting a residentially-organized approach are consistently moving residence locations to resources and provisioning individuals in the same way, we should expect their sites to have a similar tool signature across their settlement range. This should result in relatively-high intra-site tool diversity and low inter-site tool diversity, since most sites should look the same, but a variety of activities would have been performed wherever a group camped (Graf 2010; Kelly 1988; Kuhn 1995; Odell 1996; Smith et al. 2013b).

In contrast, logistically-organized populations with lower mobility tend to focus on provisioning places rather than people. For these groups, toolstone tends to be brought to residential locations where it supports a wide range of activities associated with numerous resources. Conversely, residences may be located near toolstone sources. In either case, lithic raw material is generally abundant near residential sites, resulting in less tool reuse and resharpening. Additionally, there tends to be extensive use of expedient, informal tools that can be quickly made for the tasks at hand. Away from residences, logistically-organized populations will individually provision small groups tasked with resource acquisition. These groups are expected to travel away from the residential bases to acquire resources not locally available such as plant or animal foods or lithic raw material. As a result of this disparate provisioning strategy, sites on the landscape will have low intra-site tool differences for sites associated with logistical groups accomplishing specific tasks. Residential locations are expected to have high intra-site tool differences due to a higher number of tasks being accomplished at these locations. These differences result in high inter-site differences as different site locations would have been associated with disparate numbers and types of tasks (Graf 2010; Kelly 1988; Kuhn 1995; Odell 1996; Smith et al. 2013b).

I use these models to inform interpretations of site and landscape use across time and space in the WLB, contributing to the discussion by showing that, while age components relate to changing patterns of mobility and social organization within the Walker Basin, landforms have a stronger correlation to the patterns observed.

1.1.4. Models of Landscape Use in the Great Basin

Models for landscape use in the Great Basin are largely temporally based, but they all follow the same general structure. Populations reliant on wetland resources are expected to be less mobile and use a wider range of resources whereas populations using more upland and non-wetland resources should be more mobile and target specific resources. Below I detail some of the dominant models for landscape use in the region.

In the Great Basin, the Paleoindian period is correlated to a unique subsistence strategy focused on smaller game, plant use, and open-air locations on lake and marsh landforms (Adams et al. 2008; Bedwell 1973; Campbell et al. 1937; Cummings 2004; Duke and Young 2007; Goebel et al. 2011; Grayson 2011; Hockett 2007; Jones et al. 2003; Rhode and Louderback 2007; Smith et al. 2020; Thomas et al. 1983). These expectations have resulted in two models of foraging and land-use in the Pleistocene Great Basin. The tethered-wetland model argues Pleistocene populations focused primarily on lacustrine and marsh resources while the mobile-forager model argues against any restriction to land-use by these populations based on these resources (Beck and Jones 2011; Bedwell 1973; Jones and Beck 1999; Simms 1988).

During the Holocene, the limnosedentism model argues that Great Basin populations reduced mobility whenever they exploited lacustrine and marsh resources. This model is supported by the homogeneous floral and faunal materials found on sites near these resources as well as the fact that they tend to only be found near lakes and marshes (Heizer 1967; Thomas 1985). The contrasting limnomobility model acknowledges the use of lake and marsh resources, but contends that the absence of non-wetland resources at nearby sites does not exclude the use of such resources. Instead, this model argues that the low rank of marsh and lake resources would have required regular movement between these patches as well as the regular exploitation of non-wetland resources (Thomas 1985).

For the late Holocene, another adaptive dichotomy has been developed based on travelers and processors to explain the expansion of Numic speaking populations across the Great Basin. In this model, travelers that made use of a relatively narrow set of high-ranked, geographically-scattered resources were out-competed by Numic "processors" that made use of a wider range of high and low-ranked resources at each resource patch. By spending more time processing local resources, they exploited more of each patch, resulting in less mobility and leaving fewer resources neighboring travelers to exploit (Bettinger 1994; Bettinger and Baumhoff 1982, 1983; Young and Bettinger 1992). Using this model, lake and marsh resources would have provided ideal processor patches for exploiting abundant resources.

While none of these models are universally accepted, the relationship between mobility, overall resource exploitation, and the type of landforms populations were exploiting is consistent. Marsh and lake resources are consistently associated with lower mobility and higher resource exploitation. Upland resources are associated with high mobility and more ephemeral resource exploitation. My research addresses the relationships presented in these models by comparing landscapes associated with wetland and non-wetland resources with site types and artifact classes. As a result, this study demonstrates the nature of exploitation a regional scale, addressing questions about the geographic variability of technological organization across the WLB.

1.2. Geographic Setting and Research Area

This research is based in the Walker Lake basin, a high-elevation (1,193 meters above sea level [masl]) perennial lake basin located on the western edge of both Nevada and the Great Basin. The basin runs north/south and is situated between the Wassuk Range to the west and the Gillis Range to the east. Generally, it consists of a gradual slope north and south of the lake, while alluvial fans give way to steep, rugged mountains along the eastern and western boundaries of the basin. The primary feature within the WLB is Walker Lake. It is ~24.4 m deep, has a current surface area of ~12,140.5 hectares, and a watershed of ~10,500 km^2 (BLM 2015; NDOW 2012). The lake floor tends to have a gradual slope to the north, south, and east. To the west the lake floor abruptly rises to the shoreline, where a steep slope continues into the Wassuk Range and the nearby mountain peaks (Figure 1.1).

The lake is primarily fed by the Walker River which has two tributaries, the West Walker and East Walker branches. These are fed by snowmelt from the Sierra Nevada Mountains. The rivers combine south of Mason Valley to form Walker River, which flows northwest through the Valley before turning south and flowing into the north end of Walker Lake. Water flow into the Walker River and Walker Lake primarily occurs

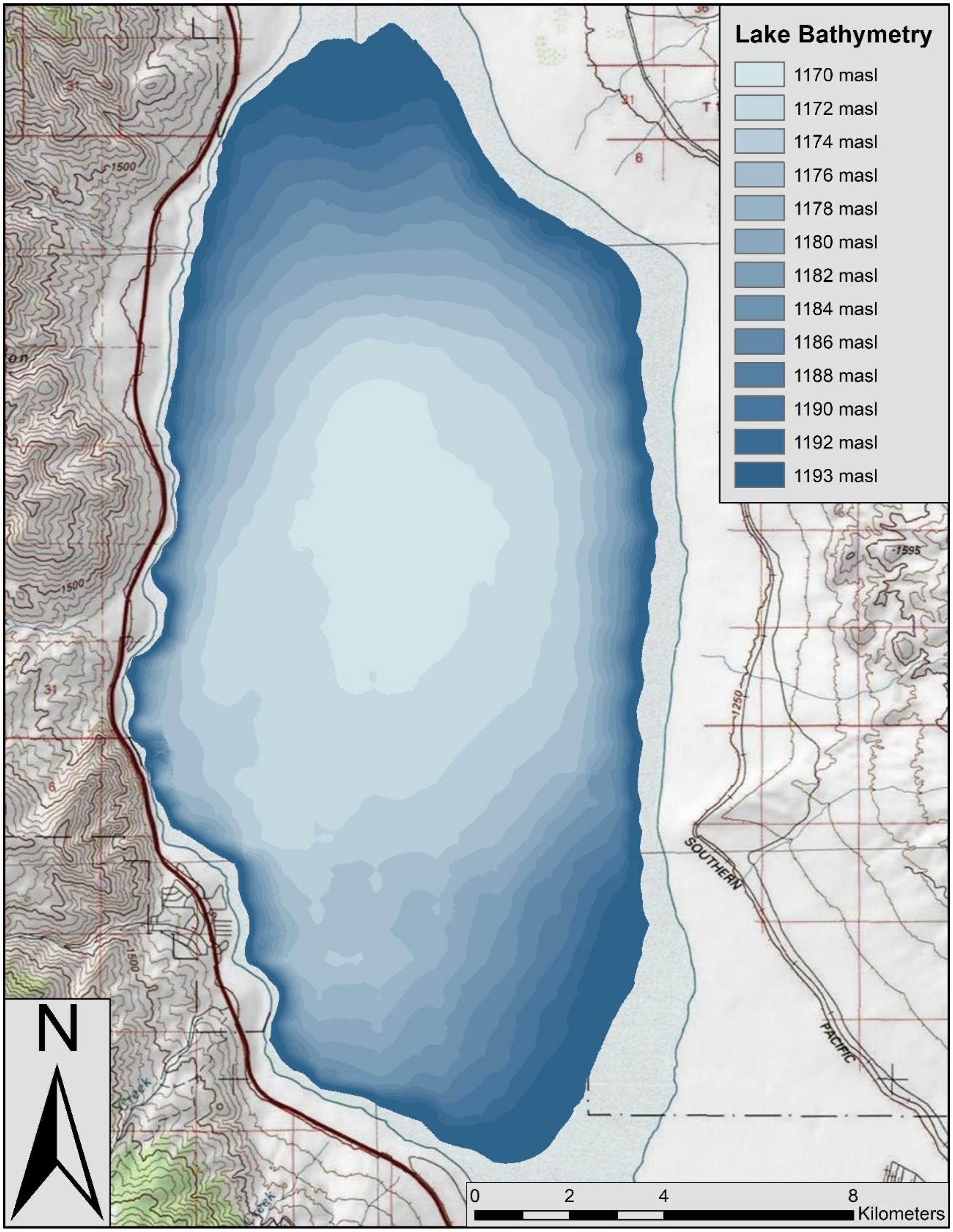

Figure 1.1. Bathymetric map of Walker Lake at the 2019 lake level. Bathymetric data from Lopes and Smith (2007) and topographic basemap (National Geographic Society 2013) modified by author in ArcMap 10.6.

from spring to mid-summer (Adams 2007; Beutal et al. 2001). The Walker River has been artificially diverted for agricultural use for ~140 years, resulting in a drastic recession of the lake. From its historic highstand of 1,252 masl in 1868 (Adams 2007) the lake has fallen to a current level of 1,193.4 masl (Lakes Online).

Within the WLB, vegetation near the lake or river in sediments with pH higher than 6.4 and high groundwater content consist of alkali meadow communities dominated by alkali sacaton (*Sporobolus airoides*) and inland saltgrass (*Distichlis spicata*). Other species include indian ricegrass (*Achnatherum hymenoides*), Baltic rush (*Juncus balticus*), and creeping wild rye (*Leymus triticoides*). In dryer sediments, the floor of the Walker Basin is dominated by playa and xeric shrub communities. These mostly consist of greasewood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Ericameria nauseosa*), shadscale (*Atriplex confertifolia*), horsebrush (*Tetradymia* sp.), and fourwing saltbush (*Atriplex canescens*). Indian ricegrass can also be present in these communities. As one travels upriver xeric communities are replaced by riparian shrub. These communities include free-standing patches of coyote willow (*Salix exigua*), buffaloberry (*Shepherdia* argentea), and Wood's rose (*Rosa woodsii*) as well as grasses such as Baltic rush, creeping wild rye, and basin wild rye (*Elymus cinereus*). Much of the lower Walker River valley has been subject to the growth of invasive tamarisk trees (*Tamarix ramosissima* and *Tamarix chinensis*) which have replaced the native willows. Freemont cottonwood (*Populus fremontii*) and black cottonwood (*Populus balsamifera*) trees are present across the lower basin where current or past homesteads are located. These mark mature cottonwood communities with xeric understory consisting of big sagebrush

(*Artemisia tridentata*), greasewood, rabbitbrush, and fourwing saltbrush. Above the basin floor at higher elevations, big sagebrush communities dominate. These include big sagebrush, rubber rabbitbrush, antelope bitterbrush (*Purshia tridentata*), greasewood and graminoids such as creeping wildrye, basin wildrye, and inland saltgrass. Still higher in the surrounding foothills and lower mountain elevations are the pinyon-juniper woodlands, including single leaf pinyon (*Pinus monophyla*), Utah juniper (*Juniperus osteosperma*), and shrubs such as big sagebrush, bitterbrush (*Encelia farinose*), and ephedra (*Ephedra nevadensis* and *Ephedra viridis*). Above the pinyon-juniper woodland, the alpine zone includes includes various trees such as lodgepole pine (*Pinus contorta*), limber pine (*pinus flexilis*), aspen (*Populus tremuloides*), mountain mahogany (*Cercocarpus ledifolius*), and undifferentiated *Salix* (Collopy and Thomas 2010; Fleishman 2019; Grayson 2011; Otis Bay Ecological Consultants 2009).

The research area included in this study consists of areas around Walker Lake and the Walker River Valley hydrographically below Mason Valley. It is 5776 km^2 and includes the lower ~52 km of the Walker River (Figure 1.2). All known precontact archaeological sites within the research area were identified and reviewed during archaeological analyses. Fieldwork was focused near the shores of Walker Lake or within Walker Lake itself. Terrestrial field research was directed toward landforms and landscapes no more than 15.8 km north of the river/lake confluence. I also investigated shoreline features east of Walker Lake but below the foothills of the Gillis Range. Underwater research focused on locations associated with minimal surface slopes and preserved and buried lake and fluvial features. This approach allowed me to target

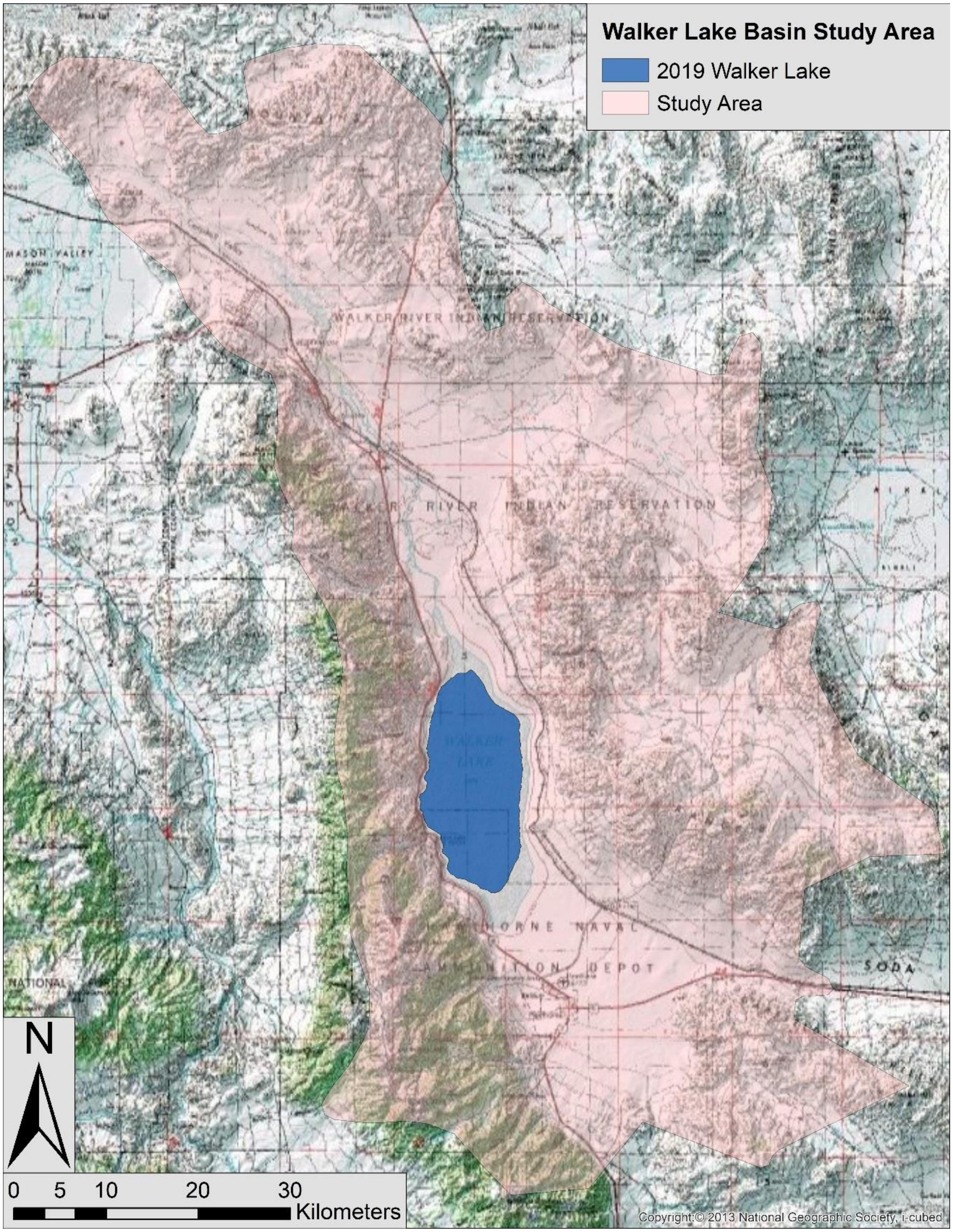

Figure 1.2. Study area within the Walker Lake basin.

previously uninvestigated portions of the WLB during fieldwork and include the broader WLB landscape for analyses and interpretations.

1.3. Research Questions and Organization

This dissertation is separated into a series of independent but related sections that summarize the research methods, the new geomorphological and environmental data, the new archaeological data, and the analyses and conclusions about the archaeological and environmental history of the WLB. These sections focus on a series of research questions:

1) Can terrestrial and underwater methodological approaches be combined in the WLB to acquire useful data broadening the archaeological record and our understanding of the environmental, climatic, and geologic history of the region?
2) Are there preserved lacustrine or fluvial features buried within Walker Lake that can clarify questions about the lake's lowstand levels, the timing of recessions and transgressions, and/or changes in the local environment?
3) Does evidence for lake levels, including upland features and materials buried within the lake, help to clarify the timing of lake-level changes across the landscape and the mechanisms for these changes?
4) Can proxy records from the WLB reveal information about the local environment?

5) Does the archaeological record of the WLB demonstrate that past populations practiced particular landscape-use and behavioral adaptations during different temporal periods?
6) Does the archaeological record of the WLB demonstrate that past populations adapted different strategies for land use and exploitation based on the landscape features they were occupying?
7) How does the WLB archaeological record compare to models of Great Basin landscape use, nearby sub-basin archaeological records, and the local environmental record?

Section 2, focuses on the different methodological approaches I used in the WLB. This section addresses the first research question, demonstrating the effectiveness of taking a multi-disciplinary approach that includes both terrestrial and underwater methodologies. It provides a brief overview of the challenges of Great Basin research and why the WLB is an ideal location for taking a multi-disciplinary approach. I then describe the different methods adopted and summarize the data acquired with each of these methods. This section highlights the importance of gathering data from sources across the region to understand the environment and its relationship to the archaeological record. It concludes by showing the inherent value of an interdisciplinary approach for understanding human adaptations and behaviors in the western Great Basin.

Section 3 addresses the geomorphological and environmental aspects of this study, addressing research questions 2, 3, and 4. It reviews the methods used to acquire new geomorphological and environmental data and then details the results of these investigations, fully describing the new information. The results are discussed based on their pertinence to each of the research questions, highlighting the presence of preserved underwater features, presenting new information about the history of Walker Lake, and showing how the paleoecological materials recovered help to clarify the environmental record. This section concludes by presenting an updated lake-level curve for the late Holocene, comparing the new curve to broad environmental changes to investigate mechanisms for shifts in Walker Lake elevation, and then discusses broad conclusions about environmental productivity and stability during the last millennium.

Section 4 investigates the archaeological record within the WLB, combining information from the new sites identified with information from previously recorded archaeology. This section focuses on research questions 5, 6, and 7 using a statistical approach to identify and highlight patterns of landscape use across both time and space. It provides a general overview of field, laboratory, and statistical methods adopted for my analyses and then describes the dataset of sites and artifacts used in the research. The results detail the patterns of landscape use observed across the statistical tests, and these are discussed in the context of the western Great Basin archaeological record, Great Basin landscape-use models, and local environmental changes. This section concludes by highlighting the relationship between the WLB archaeological record and regional expectations for changes in mobility, technological organization, landscape use, and local environments.

Finally, Section 5 summarizes the conclusions of each section, discussing their overall implications for understanding the archaeological record of the WLB. It emphasizes the inherent relationship between humans and their environment, and how the approaches adopted investigated this relationship to improve the regional record. I expand on the conclusions to highlight how this study demonstrates a valuable, broad approach to regional research for better understanding past behaviors, cultural adaptations, and environmental changes. This dissertation concludes by identifying specific areas where this study and its associated methods can be expanded and/or adopted during future work both within the Walker Lake basin and across the Great Basin in general.

2. COMBINING UNDERWATER AND TERRESTRIAL RESEARCH APPROACHES IN THE GREAT BASIN DESERT, WALKER LAKE, NEVADA*

2.1. Introduction

The value of underwater archaeological precontact research is demonstrated by the important information, discoveries, and analyses that are pursued in the field (e.g. Duggins et al. 2018; Halligan et al. 2016; Smith 2018; Garrison and Hale 2020). There is little doubt that research on sites that are inundated, waterlogged, or otherwise associated with submerged and wet environments often reveal exceptional data and preserve unique materials. Wet sites such as Windover and European bog burials contain important information about complex cultural behaviors while improving our understanding of population health (Coles 1988; Cronin et al. 2007; Doran 2002). Underwater sites can also preserve perishable materials rarely observed in the record. Little Salt Springs contained human soft tissue, examples of carved and modified wood, and various other cultural components (Clausen et al. 1979; Wentz and Gifford 2007). At Bouldnor Cliff in the UK, peats and wood were found in association with lithic materials (Momber 2000). In some cases, the combination of well-preserved materials and well-preserved contexts at underwater sites reveals important information about early human occupation in the Americas. Page-Ladson provided clear datable context for human artifacts

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associated with megafauna in Florida 14,500 calendar years before present (cal BP) (Halligan et al. 2016). Human remains at Hoyo Negro in Central America similarly demonstrated human presence 12,900-12,700 cal BP (Chatters et al. 2014).

Such sites are invaluable for understanding the ancient human experience. The above examples, however, demonstrate the broader perception that underwater precontact archaeology is only justified by exceptional results. Concerns about the cost, time, and success of underwater investigations are common, leading to the impression that underwater research is excessive or unnecessary when compared to standardized methodologies above the waterline. Yet, as Lemke (2020) highlights, these critiques neglect the methodological developments and theoretical importance of underwater precontact archaeology. Efforts to research and reveal drowned landscapes are essential for understanding past cultures. Such landscapes consist of lived-in environments where people pursued their lifeways for generations, often shaping their culture in response to the waters surrounding them (Doran 2002; Duggins et al. 2018; Faught 2004; O'Shea and Meadows 2009; Wheeler et al. 2003). Drowned landscapes also represent dynamic and changing environments that humans continuously grappled with (Balsillei and Donoghue 2004; Halligan 2020). To fully investigate past people and culture, archaeologists must not only consider landscapes that may now be underwater, but also consider how watered landscapes impacted and affected past populations (Halligan 2020). Here I highlight how archaeological research in the Great Basin of interior western North America can benefit by combining underwater and terrestrial approaches. In this paper I use these methods to develop a clearer view of the environmental setting and improve landscape reconstructions. As a result, the regional geoarchaeological context and paleoecology can be better inform the local archaeological record.

2.1.1. The Great Basin

The Great Basin of the American West includes a large portion of Nevada and Utah as well as parts of southeastern Oregon, southern Idaho, and eastern California. The region is known for basin and range geography, a high desert climate, and local topography that does not allow water to drain to the oceans (Grayson 2011). Research in the Great Basin has been driven by its geologic setting and climate history. In particular, cooler, wetter conditions prevailed between roughly 19,000-15,000 cal BP, allowing the basins to gradually fill with water and form pluvial lakes. The largest of these were to the west (Pluvial Lake Lahontan) and east (Pluvial Lake Bonneville). At the onset of the Bølling-Allerød (~15,000 cal BP), conditions warmed, resulting in lake regressions. Reversals during the Younger Dryas (12,700-11,000 cal BP) and the early Holocene (9,500-7,500 cal BP) allowed lakes to transgress, but never to their previous maxima. By the mid-Holocene, ~6,000 cal BP, most of the pluvial lakes had disappeared. While some lakes and wetlands returned during the late Holocene (after 4,000 cal BP), the region remained largely devoid of perennial water bodies (Adams 2003; Adams and Wesnousky 1988; Benson et al. 1990; Oviatt, Currey, and Sack 1992; Grayson 2011).

This history allows researchers to readily identify lake and beach landforms associated with the late Pleistocene and early Holocene, which archaeologists often use to identify associated sites (Adams et al. 2008; Beck and Jones 1997; Duke and King

2014; Graf 2001; Grayson 2011; Rhode et al. 2000). After the early Holocene, site occupations are associated with both lowlands and uplands as people focused on basin marshes and higher altitude resources (Bettinger 1991; Grayson 1991, 2011; Kelly 2001; Thomas 2014a; 2014b; Thomas et al. 1988). Across much of the Great Basin, interspersed cycles of deposition and erosion forming archaeological lag deposits and a minimal amount of recent sediment deposition allows ancient sites to be readily visible on the surface (Grayson 2011). As a result, many surface sites are palimpsests conflating multiple occupations (Goebel 2007; Grayson 2011; Jones et al. 2003). Unfortunately, these sites are poorly preserved and largely bereft of datable features and/or perishable artifacts, consisting mostly of lithic debris. To combat this, archaeologists have investigated rock shelters and caves where sediment deposition and improved preservation provide clearer occupational and temporal separation, subsistence data, and environmental information (e.g. Graf and Schmidt 2007; Grayson 2011; Heizer et al. 1970). Rare open-air sites have provided buried contexts for site occupations such as Alta Toquima (Thomas 2014a; 2014b), Sunshine locality (Huckleberry et al. 2001), and Stillwater Marsh residential sites (Raven 1990; Zeanah et al. 1995).

Through these research efforts, archaeologists have revealed the importance of a watered landscape to past peoples in the Great Basin and continue to look for these features on the landscape. While an important focus of Great Basin research includes relic lacustrine landforms as well as ancient wetlands, perennial water bodies still exist in the Great Basin as valuable research areas. Many of these are the result of human-made structures such as dams and watering ponds that often contain archaeological sites

(Puckett 2014**)**, but their potential for revealing relevant data about cultural adaptations to the precontact watered landscape remains uncertain. Conversely, there remain a select number of natural, perennial lakes in the Great Basin that provide an opportunity to study the relationship between people and water throughout time. Walker Lake in western Nevada is one such example.

2.1.2. Walker Lake

Walker Lake is a large, natural, perennial pluvial lake located on the western edge of the Great Basin. It is surrounded by the Wassuk Range to the south and west, the Gillis Range to the east, and the Terrill Mountains to the north (Figure 2.1). Currently the lake is ~12,140.5 hectares in size with a maximum depth of ~24.4 m (BLM 2019; NDOW 2012). It is fed by the Walker River, but modern agriculture and river diversions result in little water reaching the lake (Beutel et al. 2001). A complex series of lake-level changes, shown in Figure 2.2, have occurred since Walker Lake was connected to Pleistocene Lake Lahontan about 15,700 cal BP From the late Pleistocene to the mid-Holocene, current models show Walker Lake as either desiccated or a low saline marsh (Benson and Thompson 1987; Bradbury, Forester, and Thopson 1989; Newton and Grossman 1988). After 5,500 cal BP, Walker Lake levels underwent repeated rise and fall, often across extensive elevations (Adams 2007; Adams and Rhodes 2019; Lopes and Allander 2009; Yuan et al. 2006). Most periods of low lake levels since 15,700 cal BP are theorized to be the result of diversion of the Walker River into the Carson Sink through Adrian Gap, north of Walker Lake. There is some evidence that climate change

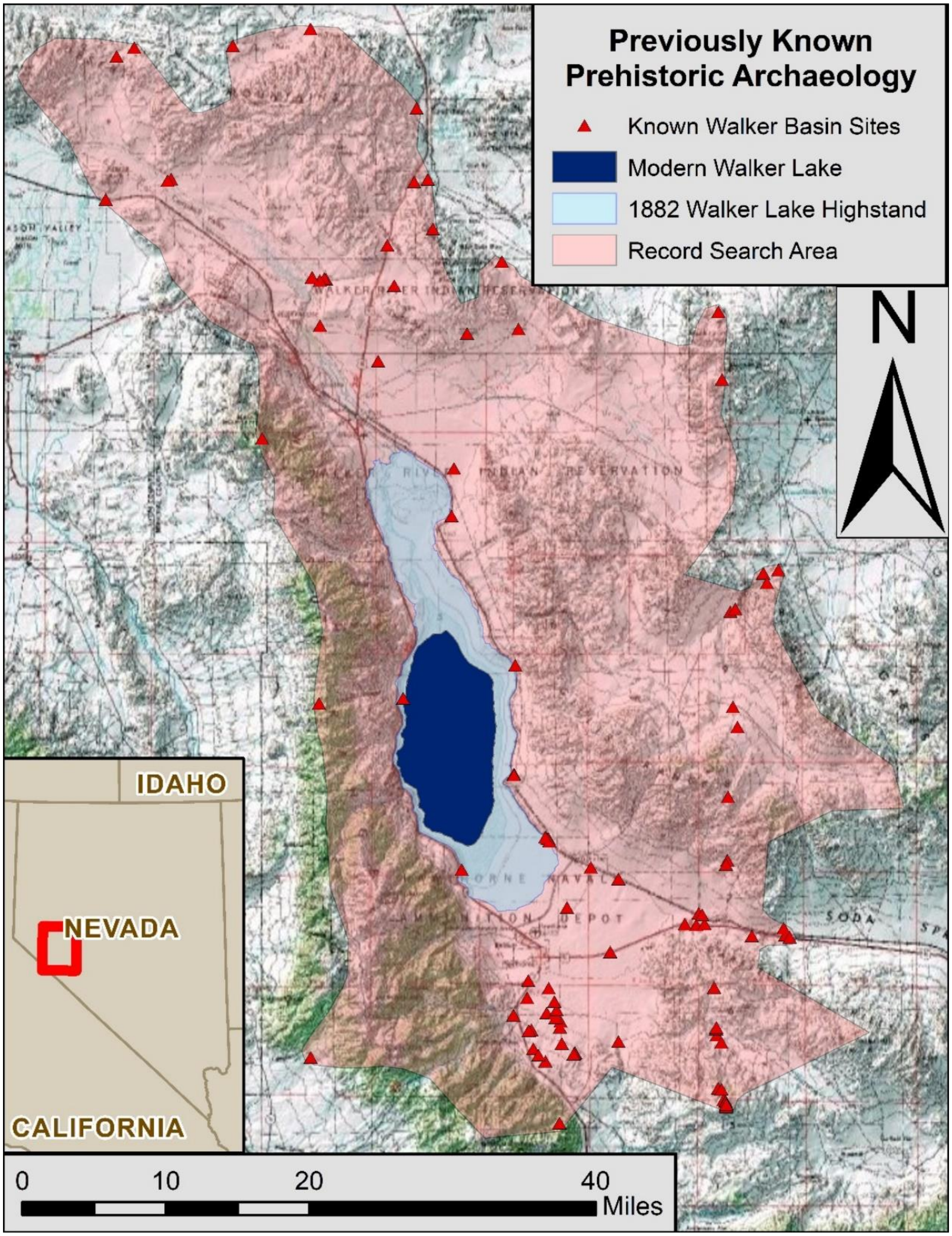

Figure 2.1. Map identifying the location of Walker Lake, the record search area of the lower Walker Lake Watershed, and sites recorded prior to the research described in this paper. Topographic basemap (National Geographic Society 2013) and inset map (ESRI 2017) modified by author in ArcMap 10.6.

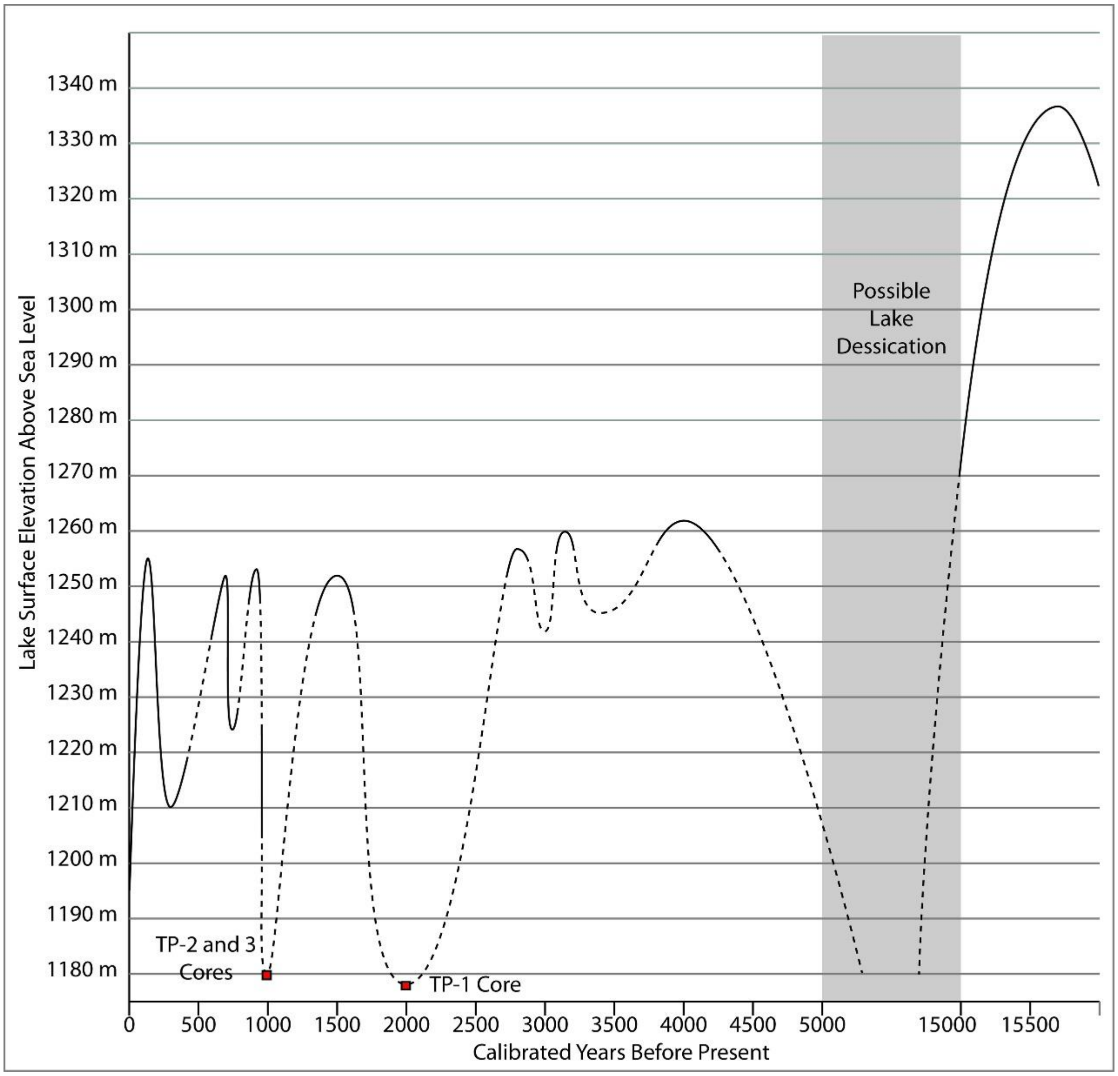

Figure 2.2. Graph showing Walker Lake's surface elevation through time. Walker Lake was likely desiccated or a shallow marsh between 15,000 and 5,500 cal BP. Upper elevations are established by Adams and Wesnousky (1998), Adams (2007), and Adams and Rhodes (2019b). Dotted lines represent elevation uncertainty. Red boxes identify the elevations of dated deposits from the 2017 cores.

also impacted lake level, but this may have been secondary to river avulsion (Adams 2007; Adams and Rhodes 2019b).

There are, however, limitations to the existing dataset. The late Pleistocene/early Holocene chronology is based on bulk radiocarbon samples dated using standard radiometric methods and ~8.5 m of the ~9 m of core sediments associated with this period were not in primary context (Benson 1988; Bradbury et al. 1989). Since lakes transgressed across the Great Basin during the Younger Dryas and early Holocene, the use of problematic dates and the absence of sediments from these periods pose a challenge to the associated lake-level model. Additionally, geomorphic research into the lake's late Holocene history has focused on sediments above the water level, providing no information about features preserved underwater. These limitations provide impetus for improving our understanding of the lake's history, both paleoecologically and archaeologically.

A record search completed by the author in 2014 and 2015 identified numerous archaeological surveys in the Walker Lake basin prior to 2014. These were most common at the southern end of the lake and are generally associated with the Hawthorne Army Depot, roadways, railroads, and powerlines. Limited previous work also extends north around the upper Walker Lake basin and Walker River valley (Giambastiani 2005, 2007; Rhode 1987). A total of 100 precontact archaeological sites were previously identified in the lower Walker Lake watershed (Figure 2.1); however, only 10 precontact sites were recorded below the lake's historic (1868) highstand prior to 2014-2016. The dearth of existing research in the lower Walker Lake basin, the lake's complex water level history, and the repeated shifts of the Walker River channel make the region ideal for combining both terrestrial and underwater research efforts. This is especially true north of the lake where Walker River flows. Ethnographic research demonstrated that the river and northern lake shorelines were used by the Northern Paiute as camps, residential areas, and fishing centers (Fowler 1990; Fowler and Park 1989). The research described below establishes the effectiveness of combining terrestrial and underwater approaches to better understand the archaeological and precontact watered landscapes around Walker Lake.

2.2. Terrestrial Survey: 2014-2016

2.2.1. Methodology

Terrestrial survey completed in the Walker Lake basin focused on the modern Walker River Channel, relic river channels, and relic shorelines. The Walker River channel survey conducted in 2014 began at the confluence with Walker Lake and ended upriver 2.78 km. Both the eastern and western cutbanks were visually inspected for archaeological deposits and stratigraphic markers indicative of preserved, buried shoreline deposits. The first terrace of Walker River was also visually surveyed for archaeological materials 10-30 me from the cutbank. In 2015, survey targeted relic shoreline deposits associated with the Sehoo highstand east of Walker Lake and the historic highstand north of Walker Lake. These landforms were searched using 30-m-transect visual-walkover survey and followed the lacustrine landforms to identify any

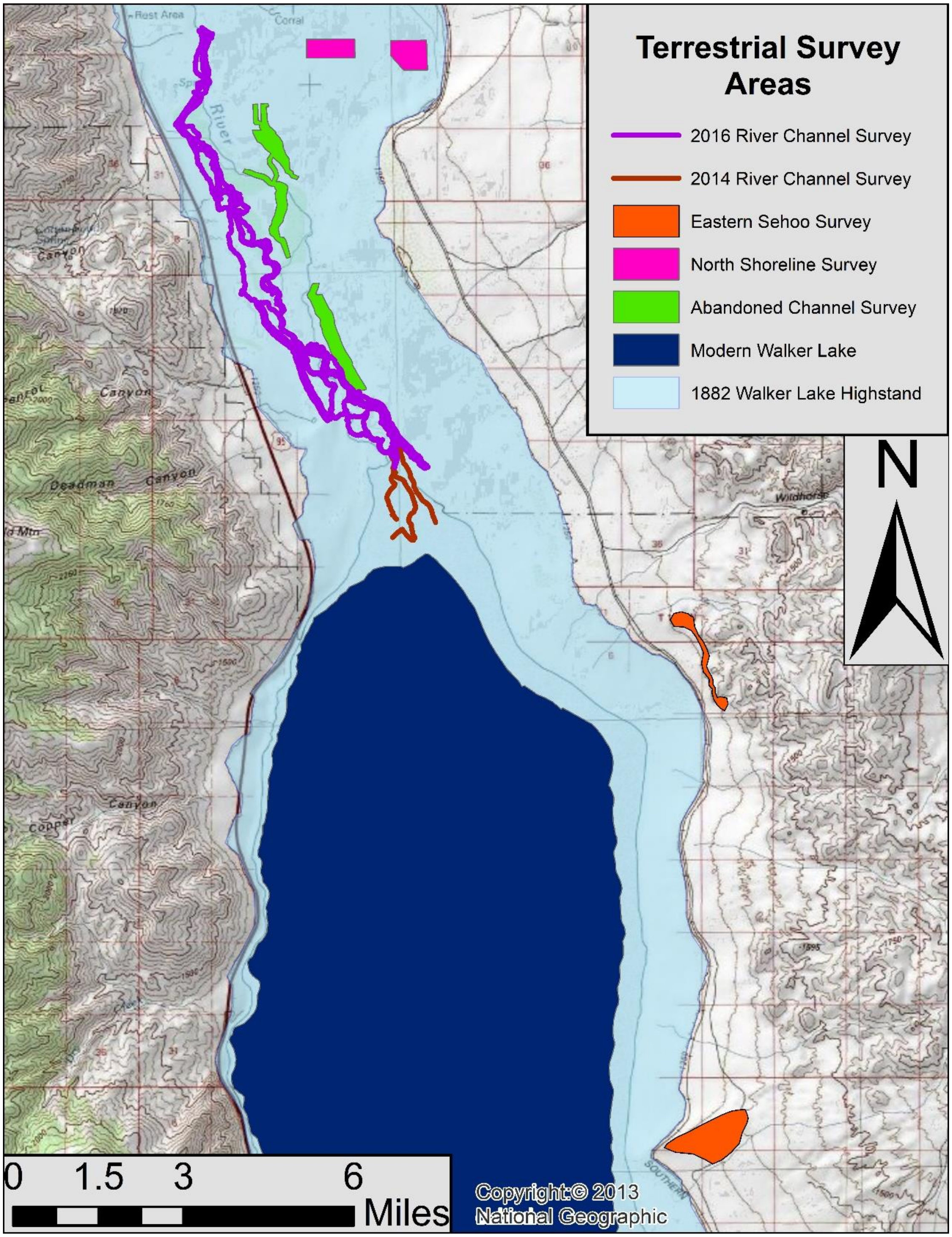

Figure 2.3. Map showing the 2014-2016 terrestrial survey areas in the Walker Lake Basin. Topographic basemap (National Geographic Society 2013) modified by author in ArcMap 10.6.

preserved archaeological materials. Finally, the 2016 survey targeted the Walker River cutbank from 2.14 to 15.8 km north of the Walker River/Walker Lake confluence as well as relic Walker River channels east of the modern river. This survey followed the methods established in 2014 and 2015 (Figure 2.3).

2.2.2. Results

A total of 15.8 km, straight line distance, of the lower Walker River cutbank was surveyed for archaeological material and preserved stratigraphy indicative of changing water levels. The only site identified during this portion of the survey was on the eastern Walker River terrace, which was also affiliated with a relic channel. We also located 18 isolates (less than 10 flakes in a 10-x-10-m area), mostly consisting of small obsidian flakes in the river channel. One large, deep mortar was also observed in a cluster of granite rocks in the river channel (Appendix A:Figure A.3.a). We recorded 12 stratigraphic profiles that preserve evidence for changing lake levels. These mirror the cutbanks recorded by Adams (2007). Within these cutbank profiles, we recorded tephra deposits ~3.86-5.63 km north of Walker Lake and noted similar tephra deposits in cutbanks to the north and south. Based on the tephra's recorded depths in the stratigraphic column and the distribution of tephra deposits documented by Sieh and Bursik (1986) it is likely that the recorded tephras resulted from the North Mono Eruption dating to 650 cal BP (Bursik et al. 2014). Future analysis of the tephras will confirm their source and exact time of deposition.

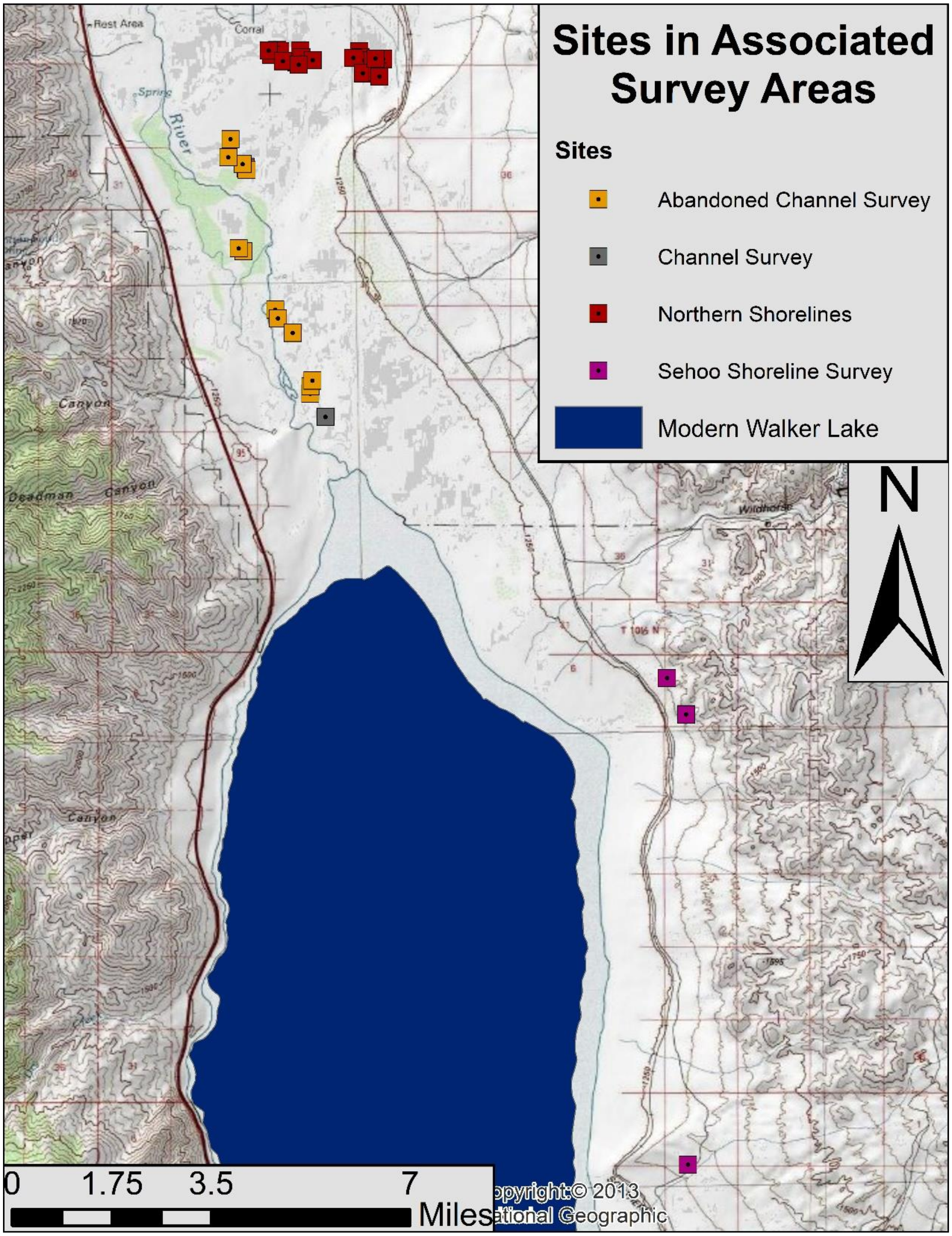

Figure 2.4. Map showing the newly identified archaeological sites and their associated survey areas. Topographic basemap (National Geographic Society 2013) modified by author in ArcMap 10.6.

Walk-over survey associated with relic shorelines and river channels identified 37 new precontact sites and 30 isolates (Figure 2.4). The number of sites associated with each landform and their temporal contexts are listed in Table 2.1 (all diagnostic artifacts were typed using the Monitor Valley key [Thomas 1981] and dated using the chronology established by McGuire [2002] and Hildebrandt and King [2002]; see Appendix A: Figures A.1-A.2 for examples of temporally associated artifacts). Initial spatial comparisons of site distributions from different temporal periods show that the relative elevation of sites across the basin changes during different chronological periods. For this analysis, elevations were separated into three ranges: those below the historic highstand (1,255 masl), those between the historic highstand and the Sehoo highstand (1,255-1,338.8 masl**)**, and those above the Sehoo highstand. While these elevations appear arbitrary, they were chosen to provide a general delineation between sites that would have been underwater during the historic period, those that are likely directly associated with Walker Lake basin landscape use, and those that are associated with upland elevations and thus indirectly associated with lower lake basin and river valley resources (Rhode 1987). Table 2.2 identifies the number of sites in each elevation range and compares the number of sites in each temporal period with their elevation range.

Table 2.1. Newly identified sites categorized by survey landform and temporal component.

Landform	Total 2015-2016 Sites	Paleoindian Component (Human Entry to 7,000 cal BP)	Early-Middle Archaic Component (5,000-1,350 cal BP)	Late Archaic Components (1,350-600 cal BP)	Late Prehistoric Component (600 cal BP-Contact)	Multiple Component
Northern Beach Ridge	21	2	3	4	11	5
Eastern Sehoo Shoreline	3	1	2	0	1	1
Abandoned River Channels	14	0	3	3	0	1

Table 2.2. All known prehistoric sites in the lower Walker Lake watershed identified by elevation range and temporal component.

Elevation (m)	2015-2016 Sites	Previously Recorded Sites	Paleoindian (Human entry to 7,000 cal BP)	Early-Middle Archaic (5,000-1,350 cal BP)	Late Archaic (1,350-600 cal BP)	Late Prehistoric (600 cal BP-contact)
1194-1252	35	8	2	6	7	11
1252-1338	3	26	5	3	1	4
1338-3423	0	66	2	4	2	1

2.3. Underwater Survey and Testing: 2014-2017

2.3.1. Methodology

Underwater work at Walker Lake began in summer 2014 with visual survey of the submerged landscape off the lake's west coast. We conducted three surveys off 20 Mile Beach and two off Sportsman's Beach. SCUBA divers swam in an easterly direction from the coastline along the lake bottom looking for evidence of preserved, submerged shoreline features. After travelling ~0.8 km, divers returned to the shore underwater along a different transect. Divers remained within visual contact of one another during all diving, resulting in a transect width of ~3 m. In 2014 we also recorded sediments recovered with a 7.62-cm diameter auger in 25 cm increments to a maximum depth of 3.75 meters below surface (Figure 2.5).

In 2015, we completed preliminary underwater test excavation and coring at the northern end of Walker Lake. I selected the test location based on bathymetric data recorded in 2005 (Lopes and Smith 2007) (Figures 1.1 and 2.5). The excavation consisted of a 2-x-1-m block delineated using an aluminum excavation frame anchored into the lake sediment and excavated to a depth of 50 cm below the sediment surface in 10 cm increments. All sediments were removed using trowels and collected with a 4-inch water dredge. Sediment was screened at the water surface through nested 1/4, 1/8, and 1/16-inch mesh built into a barge platform (Figure 2.6). Archaeologists searched the screens for unique ecological materials and cultural artifacts, which were then collected for later analyses. A 7.62-inch core was collected from inside the test block, capturing 147 cm of

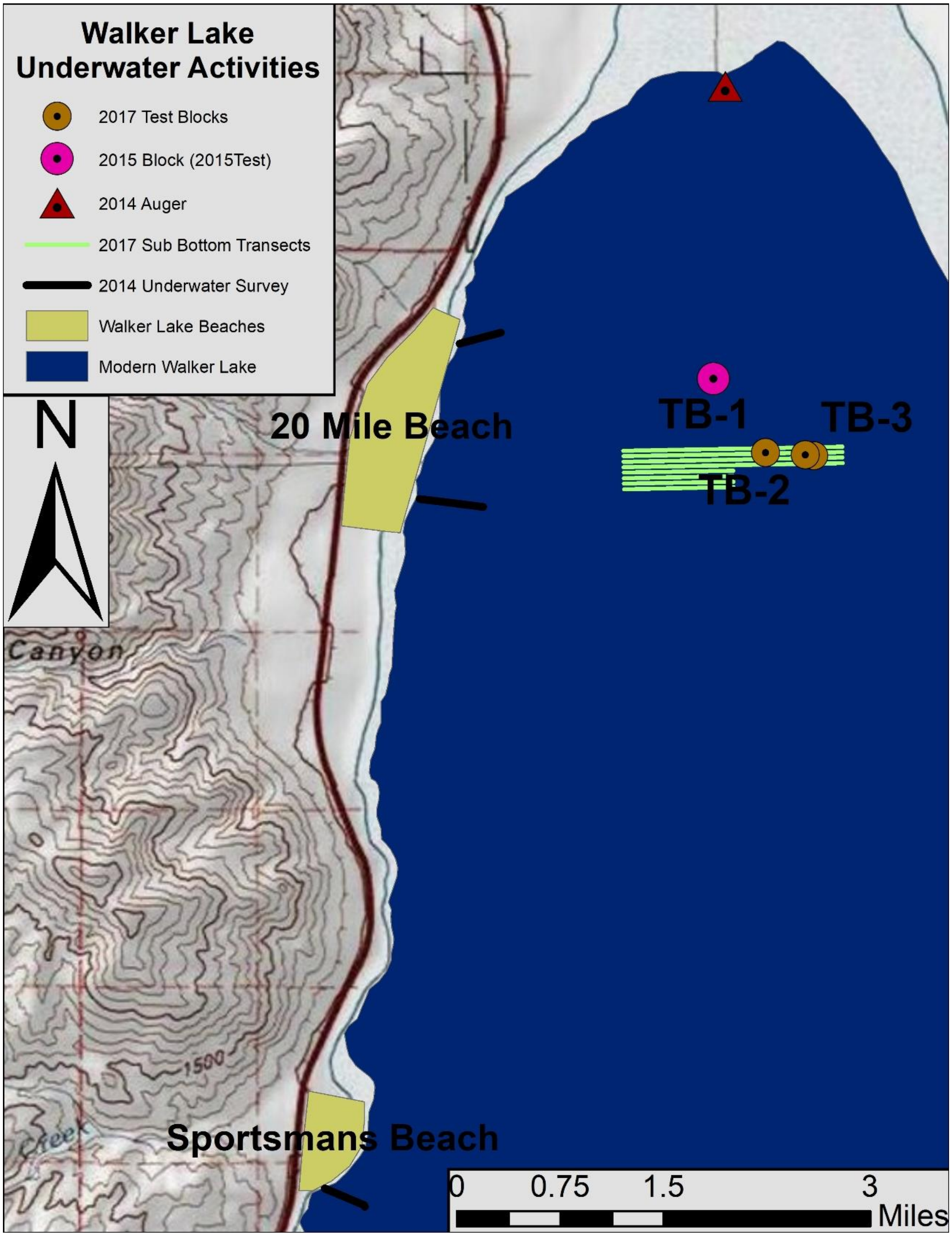

Figure 2.5. Map showing underwater survey, sub-bottom survey, and test excavation areas. Highlighted locations are research staging areas. Topographic basemap (National Geographic Society 2013) modified by author in ArcMap 10.6.

Figure 2.6. Image showing underwater test excavation equipment at the surface.

sediment. Coring and test excavation in 2015 were cut short due to mechanical failure of the project's boat motor.

In 2017, underwater work at Walker Lake resumed. This included sub-bottom profiling, test excavation of three 2-x-1-m blocks, and collection of eight sediment cores from the three excavation blocks. Sub-bottom profiling focused on an area south of the 2015 test excavation, targeting depths with less sedimentation. A total of 0.6 km^2 of the lake surface was surveyed using a 50-m-transect lawn-mower pattern. The first four transects were 1 km in length and the second four were extended to 2 km in length, capturing more of the lake's buried stratigraphy (Figure 2.5). The resulting sub-bottom stratigraphy revealed a potential shoreline and a possible river channel (Figure 2.7), the foci of 2017's underwater test block excavations.

One test block was placed where the possible buried deposits of transgressional sands stopped rising (TB-1), one test block was placed on the western terrace of the apparent channel feature (TB-2), and the last test block was placed on the eastern terrace of the same channel feature (TB-3) (Figures 2.5 and 2.7). These locations were selected to target landforms similar to those associated with archaeological sites identified during terrestrial survey. By targeting buried terrestrial features in the sub-bottom data, we also maximized the opportunity to identify datable stratigraphic changes indicative of past lake levels and environment. Excavations proceeded by clearing loose sediment from each area and then anchoring a 2-x-1-m aluminum excavation frame into the lake sediments. Each block was excavated to a depth of 2 meters below the exposed sediment surface in 10 cm increments, employing the same methodology described for 2015. All excavated materials captured by the screens were collected for later laboratory analyses. Within each test block, sediment cores were collected to capture the stratigraphic profile. Prior to excavation a core was placed in the northeast corner, at 1 m below the aluminum frame (BF) a second core was placed at the southwest corner, and within TB2 and TB-3 a core was placed centrally once excavation was completed.

All cores and collected materials were brought to the Florida State University Geoarchaeology Laboratory for analyses. I counted all materials collected from the screen and separated them by type for each 10 cm level. I cut cores using a jig and cart

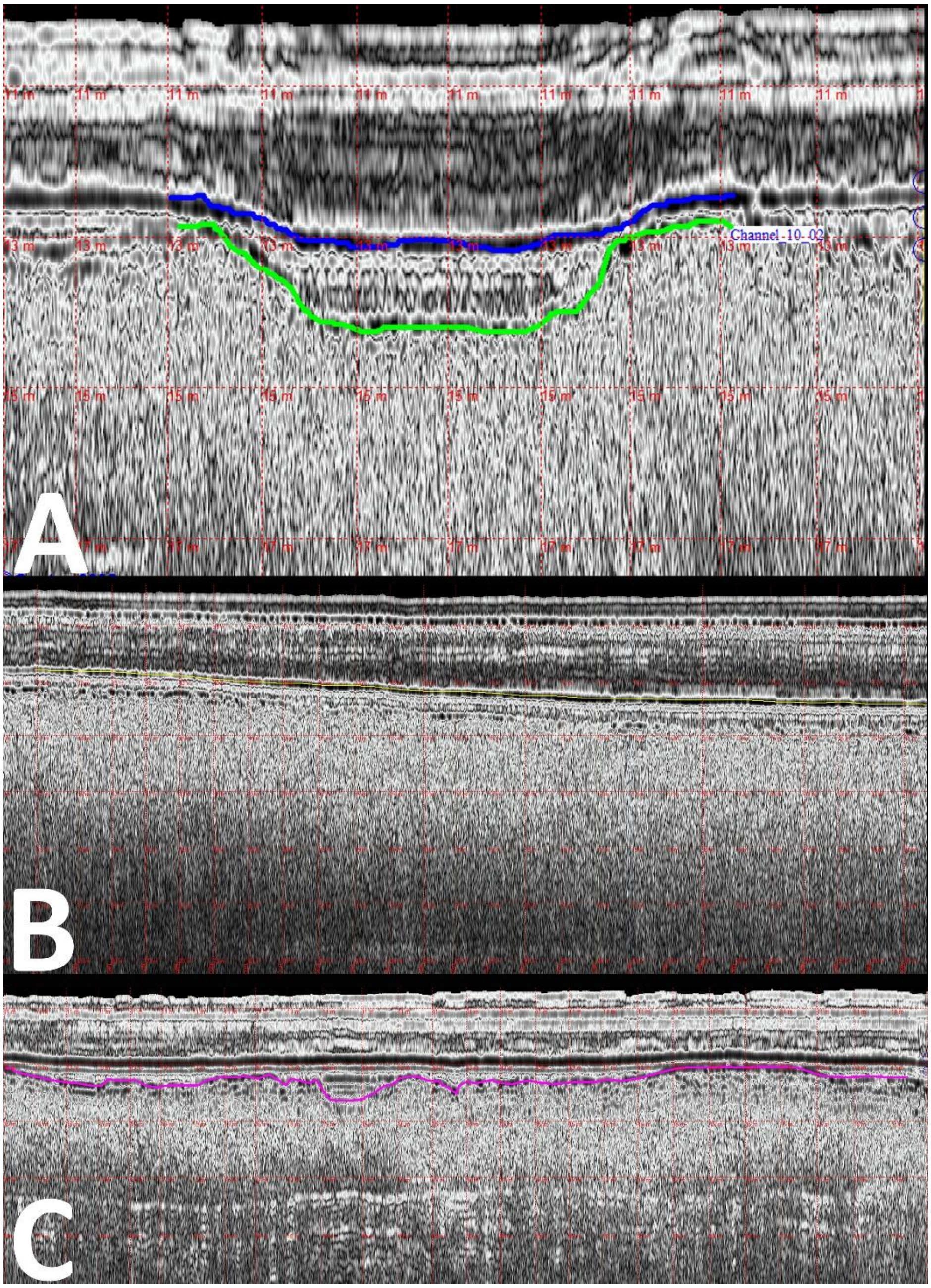

Figure 2.7. Sub-bottom profile imagery showing features discussed in the text. All profiles run from east/left to west/right: (A) Blue and green lines idntifying the upper and lower strata of the buried channel in the eastern survey area. Test Blocks 2 and 3 were placed on the western and eastern terrace of this channel respectively. (B) Yellow line showing the rising shoreline feature identified at the western edge of all sub-bottom profile transects. (C) Purple line showing the rippled sediment formations observed east of the channel shown in A.

system, after which I described the sediment profiles using standards established by the National Soil Survey Center (Schoenberger 2012). Finally, I collected organic materials from select stratigraphic units to date high energy depositional events.

2.3.2. Results

Swim-over survey from the southern 20 Mile Beach location identified a single preserved shoreline feature. This feature, at a depth of 4-4.7 mm, was confirmed by an additional transect traveling east from the drowned shoreline feature, but no additional features were found to the east. No drowned terrestrial features were found during surveys from the northern 20 Mile Beach location or Sportsman's Beach. The auger taken at the northern end of Walker Lake encountered inundated sediments at 15 cm depth. Most of the augered sediment consisted of clays, silty clays, and gleyed clays. We encountered a black sandy loam at a depth of 359 cm below surface indicative of shoreline or fluvial deposits.

The 2015 test excavation did not extend past recent silty clay lake deposits and no cultural materials were recovered. Organic materials recovered in the screen consisted of small pieces of plant material and fishbone. None of the excavated materials suggest a depositional environment other than the current lake conditions (but note that fish are no longer able to live within Walker Lake due to high alkali levels, changes in dissolved oxygen loads, and shifts in lake chemistry at depths cold enough to support fish populations [Beutel et al. 2001; Cooper and Koch 1988; Wurtsbaugh et al. 2017:820]). No materials were found *in situ* due to a combination of limited time and zero-visibility conditions. The core recovered from the test block was analyzed in the field, revealing similar deposits to those encountered during excavation. The exception was a 2.2 cm thick band of gray volcanic ash 94-96.2 cm below the surface. This tephra may be the same volcanic event recorded in the Walker Lake cutbanks.

The 2017 sub-bottom analysis identified a number of preserved sedimentary deposits below the surface of the drowned lake sediments. All survey transects showed a rising stratigraphic profile running west to east. This deposit is relatively smooth with no evidence of downcutting or other depositional disturbances (Figure 2.7A). This stratum likely represents a sand layer, which, based on the deposit's shape and length, is interpreted as a transgressing shoreline. To the east, the longer transects revealed the presence of a sudden rise and fall in the buried stratigraphic profile. This change was observed at roughly the same easting across multiple transects. The sudden change in horizontal deposition indicates the presence of a preserved stream channel buried under the modern lake (Figure 2.7B). Additional evidence of possible fluvial features was observed east of this channel as small "ripples" in the buried stratigraphic profile. These may represent rivulets or other low energy stream deposits (Figure 2.7C).

During 2017 test block excavation we removed 12 m^3 of sediment. The silts and clays excavated created blackout conditions, but we were able to use our trowels to feel and listen for changes in texture, dense organics, or cultural materials. The most notable material was a dense pocket of fish bone in the 130-140 cm BF level of TB-1. We also identified abrupt changes in the sediment from 161-167 cm BF in TB-2 and 160-176 cm BF in TB-3. These were tephra deposits, similar to that observed in the 2015 core. The tephras were ~4-5 cm thick in both excavation blocks and dipped southward. Unfortunately, no cultural materials were recovered from the excavations. The materials from the TB-1 screens included a high density of woody organic materials such as sticks, twigs, and bark fragments. TB-2 and TB-3 did not have many woody organic materials, and those recovered were generally smaller than those from TB-1. We also found fish bones in every level of each block. Other materials recovered from the screens include charcoal fragments, small shells from lake mollusks, a few plant seeds, and abundant fish scales. Stratigraphic profiles were not recorded from the test blocks due to the lack of visibility. Attempts to use lights did not improve visibility and all video and camera footage taken directly in front of the sidewalls is black. For these reasons, I report stratigraphy based on the collected cores and correlate it with the materials found during test excavation.

The two cores from TB-1 contained the deepest record of sediments. Fine grained lake sediments extended to 283 cm BF and the tephra was located between 233-228.4 cm BF. Below 283 cm, coarse-to-fine sands represent higher-energy deposits, possibly associated with the shoreline feature observed in the sub-bottom profile. The three TB-2 cores contained lake deposits to a depth of 220 cm BF. The tephra was present between 173.8-177.7 cm BF, slightly below the depths identified during excavation. Below 220 cm BF, two fining-upward sand deposits may represent shoreline materials or stream terrace deposits identified in the sub-bottom profile. The cores from TB-3 contained stratigraphy similar to TB-2. Lake deposits extend to a depth of 198 cm BF to the north and 243 cm BF to the south. The tephra deposit occurs between 152.4-

156.9 cm BF in the north and 190.5-195 cm BF in the south. These differences reflect extensive dipping. Below the lake deposits, a sandy clay capping a series of fining-upward sands reflect higher energy deposits. The bottom of the cores contained interfingered clay and sandy clay loam over a dense, low-energy clay deposit.

A suite of radiocarbon dates from the 2017 cores date the deep, higher energy sands. Woody samples from terrestrial plants were dated from the TB-2 and TB-3 cores. The results were consistent, ranging between 785-935 cal BP, 2σ; the age medians range from 855-921 cal BP **(**all radiocarbon dates were calibrated using the Intcal13 curve in the online version of OxCal 4.3 [Ramsey 2019; Reimer et al. 2013]**)**. One outlier from the highest sand stratum of TB-3 dates to 787-700 cal BP, 2σ (Table 2.3). In TB-1, a fish bone sampled from the bottom of the southwest core returned a radiocarbon date of 2,460 ± 25, which after adjusting for the accepted 300-year reservoir effect in Walker Lake (Benson et al. 1991; Broecker and Walton 1959; Yuan et al. 2006), dates between 2291-2158 cal BP, 2σ (Table 2.3).

2.4. Discussion

Combining terrestrial and underwater research at Walker Lake allowed for mutually supportive methodologies in all aspects of the research. Terrestrial investigations used an established approach to archaeological and environmental research. I was able to use these efforts to expand the regional archaeological knowledge, quickly and efficiently investigate the Walker Lake basin with a small crew of researchers, and continue my research when underwater work was impossible due to

Table 2.3. Radiocarbon samples and calibrations from cores.

Wood Radiocarbon Samples and Calibration							
Lab No.	**C14 BP**	**Cal BP (median)**	**Cal BP (2-σ range)**	**Material**	**Stratum**	**Core**	**Depth (BF)**
4551	910 ± 15	865	910-785	Wood	TB2-II	TB-2, NE Core	154.5 cm
4552	925 ± 15	856	911-792	Wood	TB3-IIIc	TB-3, Central Core	245 cm
4553	985 ± 15	921	935-802	Wood	TB3-IIIa	TB-3, NE Core	215.5 cm
4554	965 ± 15	856	930-799	Wood	TB2-II	TB-2, S Core	226 cm
4555	920 ± 15	859	911-790	Wood	TB2-II	TB-2, Central Core	224 cm
4556	970 ± 15	899	931-800	Wood	TB3-IIIa	TB-3, SW Core	249 cm
4557	965 ± 20	855	930-797	Wood	TB3-I	TB-3, SW Core	270 cm
4683	840 ± 20	746	787-700	Wood	TB3-IIIc	TB-3, SW Core	244.5 cm

Fish Bone Radiocarbon Sample and Calibration												
Lab No.	**C14 BP**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**%C**	**%N**	**C:N**	**Cal BP (median)**	**Cal BP (2-σ range)**	**Material**	**Stratum**	**Core**	**Depth (BS)**
5088	2460 ± 25	-17.9	8.1	22.6	8.4	3.15	2,229	2,291-2,158	Fish Bone	TB1-Ia	TB-1, SW Core	278 cm

Radiocarbon samples dated at the Penn State AMS Radiocarbon Laboratory. 14C dates calibrated using the Intcal13 curve in the online version of OxCal 4.3 [Ramsey 2019; Reimer et al. 2013]. A 300-year reservoir effect was applied to the fish bone OxCal calibration curve [Benson 1991; Broecker and Walton 1959; Yuan et al. 2006].

equipment or weather challenges. Conversely, the underwater efforts were a difficult, albeit successful, logistical challenge. Since underwater archaeology can be prohibitively expensive, one of my primary goals was to complete excavation in Walker Lake within a traditional archaeology budget. I based our approach on methodologies developed in north Florida (Halligan 2012; Halligan et al. 2016; Webb 2006) but adapted them for a large lake with a history of high winds and danger to watercraft. Conditions required continuous refinement and adjustment to the excavation system to maximize our efforts and minimize hazards. The resulting system included a 4-point anchoring system, multiple boats as diving platforms, and a 10-horsepower water pump for dredging. The lake's alkali waters required the use of aluminum and stainless steel for all hardware to avoid corrosion. Even with these requirements the project was completed within the established budget and in a timely manner. Further, the personnel requirements for underwater research provided larger crews when underwater efforts were thwarted. As a result, I completed much of the terrestrial survey more efficiently and effectively than would have been possible with the small crews available in 2014 and 2016.

The terrestrial survey expanded the local archaeological record across hitherto unsurveyed landforms. These results then informed the underwater research. The 38 new precontact terrestrial sites not only increase the basin's site count by 38.6 percent, but demonstrate patterns of landscape use across lower elevations. Results indicate that during the Late Prehistoric period (600 cal BP to European contact), people took advantage of the high lake, pursuing their lifeways near the shoreline just below 1,255 masl. Site assemblages point to lithic reduction, processing activities, the possible use of nets, and successful near-shore adaptations (Appendix A: Figures A.3-A.5). The absence of Late Prehistoric sites around relic channels below 1,255 masl and near the lower Walker River indicate these populations primarily used the lake during high-water levels and occupied elevations associated with the Upper Walker River watersheds (Rhode 1987).

During the mid to late Holocene, Early (5,000-3,500 cal BP), Middle (3,500-1,350 cal BP), and Late Archaic (1,350-600 cal BP) populations camped near the river channel and streams during times of both high and low lake levels. Artifacts from these periods were found in relatively equal association with both the northern shoreline and abandoned river channels. Differences appear between these populations with respect to their use of landscapes above 1,255 masl. Late Archaic artifacts above the lower Walker Lake basin are relatively uncommon, suggesting focused wetland use. Early-Middle Archaic sites are equally distributed between elevations above and below 1,255 masl, supporting behavioral models suggesting that these populations took consistent advantage of both wetlands and upland resources (Broughton and Grayson 1993; Grayson 1991; Thomas 2014a; 2014b). While Paleoindian (human entry to 7,000 cal BP) artifacts were found across all elevation groups, they were not associated with the lower relic or modern river channels. Their presence was most common between 1,255 and 1,338.8 masl and they are both north and south of the lake. This suggests that, with the Walker River flowing into the Carson Sink, early populations living in the basin took advantage of resources associated with fluvial systems supported by watersheds south of the Adrian Gap, perhaps during wetter periods such as the Younger Dryas and early Holocene.

The results demonstrate that the nature and level of the lake was important to many groups, and that occupation primarily centered around the river and lake shorelines. Thus, underwater research required the identification of these features to determine if there was site potential. Additionally, 35 of the 38 sites discovered would have been underwater as little as 130 years ago, indicating that if the requisite features could be found within the lake, drowned sites are likely to be preserved.

All initial efforts focused on identifying preserved shoreline or fluvial deposits. The identification of one such feature during swim-over survey in 2014, in combination with finding beach deposits 3.59 m below surface in the auger, demonstrated their potential. I used excavation and coring in 2015 to determine baseline depths of lake sediments and stratigraphy. The results from 2017 sub-bottom profiling provided definitive evidence for the buried preservation of shoreline and fluvial features well below the modern lake level. It is with these results that the 2017 excavation and coring were pursued, ultimately enhancing our understanding terrestrial record.

The excavation, showing a range of organic materials at various levels, illustrate that environmental context was variable across the last one to two thousand years. Radiocarbon results and marker tephras provide temporal control for these observations. In addition to providing temporal controls of the excavation units and cores, radiocarbon dating shows the potential for bone and wood preservation within the lake for at least 700-2,200 years. The core stratigraphy clarifies the lake’s late Holocene history.

Previous lake-level research provides a well-established chronology of transgression and recession, with transgression highstands given specific elevations using data from tufas, cutbank stratigraphy, and shoreline deposits (Figure 2.2). Unfortunately, most lowstand estimates are based on models for past climate, river activity, and watershed size, leaving substantial uncertainty (Adams and Rhodes 2019b). The core data provide dated stratigraphic evidence for terrestrial landforms, establishing a minimum depth below which water levels must have fallen. The result is a better understanding of the landscape available for human occupation during the recessions dated to 860 cal BP and perhaps 2,200 cal BP.

Clearly combining terrestrial and underwater research approaches to reveal the watered landscape is effective. From the logistical challenges of completing fieldwork to providing a more complete picture of the archaeology, ecology, and environment over time, both underwater and terrestrial efforts support and inform one another. While not every research program will have the opportunity to combine these methods, when either is neglected, questions are certain to be left unanswered.

2.5. Conclusion

These research efforts illustrate an important development for coastal, lake, and water-based studies in the Great Basin. Expanding the scope of research to include areas recently drowned as well as perennial water bodies allows for new data to be recovered, new questions to be addressed, and new questions to be raised. This paper highlights the importance of investigating relic and shifting landforms to better understand the scope of landscape use at different periods. As these landforms are associated with dramatic and visible changes to the landscape, the results show how past populations were able to adapt to various lake sizes, different river conditions, and rapid environmental shifts. Underwater research within the lake demonstrates that perennial lakes are valuable sources of environmental information that can further clarify both changes to the local environment and associated human adaptations. It further shows that drowned lakes can not only contain buried, terrestrial landscape features, but that they have high potential for archaeological preservation in association with these features.

While these research efforts are a strong start for combining terrestrial and underwater methods in the Great Basin, further work is essential. Terrestrially, test and controlled excavation should be pursued on dry sites below the historic highstand. These excavations will identify how well the stratigraphy and buried contexts are preserved. Additional survey below the historic highstand, across Sehoo highstand features, and in upland environments will provide a robust archaeological record for testing hypotheses about chronology and land use. Underwater, exhaustive sub-bottom profiling across the northern half of Walker Lake will identify the range of features preserved, their depth, the best areas for human occupation, ideal coring locations, and lowstand elevations associated with various regression events. With these data, an extensive test excavation and coring program could detail submerged stratigraphic features and their archaeological potential. Sites identified during these efforts would then undergo larger-scale excavation to investigate landscape use during periods of low lake level.

These proposed efforts are well within the scope of existing archaeological research projects. In addition to using well-established terrestrial methods, this project shows that underwater testing and excavation can be undertaken efficiently to produce valuable results, whether or not archaeology is found. Combining these methodological approaches creates a more robust picture of the past. Similar approaches are useful wherever archaeologists can better understand the archaeological record by investigating nearby water sources for archaeological, geological, or environmental data. As demonstrated here, these efforts are not limited to oceanic environments, densely watered landscapes, or early temporal periods. Instead, advances in technology, improved methods, and reduced costs now allow archaeologists to combine underwater and terrestrial research approaches to better understand past peoples' adaptions to the watered landscape wherever and whenever they see fit.

3. TERRESTRIAL AND UNDERWATER INVESTIGATIONS OF THE GEOMORPHOLOGICAL AND ENVIRONMENTAL HISTORY OF THE WALKER LAKE BASIN, NEVADA

Understanding the impacts of past climate change is vital for predicting and interpreting the potential for future changes as both human and natural factors continue to affect climate through the twenty-first century. To accomplish this, geophysical, geomorphic, and environmental studies should be undertaken at varying scales. Much current environmental research addresses the large-scale spatio-temporal impacts of climate change, such as changing weather patterns (Enke et al. 2005; Fowler et al. 2007), scale of weather events (Seneviratne et al. 2012; Van Aalst 2006), and impacts to various ecological and anthropogenic communities (Chown et al. 2016; Epstein et al. 1998; Wilby 2007). It is important to view results from such studies in the context of paleoclimatic records to provide a deep-time backdrop of climatic data for comparison and understanding (Ruddiman 2018). Additionally, focused study of local environments where small-scale climate change may reflect either global or local events are uniquely informative. These studies have the potential to inform on the range and nature of impacts that are related to climatic shifts. Pollen studies from ponds, lakes, or wetlands are useful for highlighting how changing climates can impact plant communities and their ranges (Bigelow and Edwards 2001; Louderback and Rhode 2009; Wigand 1987), while geophysical and geomorphic studies show how landscapes can shift in various ways to impact a wide range of environments (Adams 2003; Adams and Wesnousky

1998; Adams et al. 2008; Donoghue and White 1995; Graf and Bigelow 2011; Oviatt et al. 1992; Schmitt et al. 2007).

In sum, the value of large-scale impact studies is undeniable, and local, regionalized research increases the resolution of data to better understand how environments are affected by climate change while revealing stark and dramatic ecological changes. Walker Lake, in western Nevada, is one basin where regional reconstruction of environments have been informative. However, continued research and additional data from the region is invaluable for clarifying the impacts that geomorphological shifts and climatic events have had on the environment.

Here I focus on a series of questions intended to clarify the late Holocene history of Walker Lake and the surrounding environment. First, are there preserved lacustrine or fluvial features buried within Walker Lake that can answer questions about lake lowstand levels, the timing of recessions and transgressions, and/or changes in the local environment? Second, does evidence for lake levels, including upland cutbank stratigraphy and drowned and buried features within the lake, help to clarify the timing of lake-level changes across various parts of the landscape? Finally, can proxy records from the Walker Lake Basin reveal information about the local environment such as where and how lake-level fluctuations occurred, how floral/faunal productivity changed, or how events such as eruptions impacted the region?

This paper discusses a suite of methodological approaches used to improve the resolution of the Walker Lake record and provide an update to Walker Lake history and local environmental change. First, I employed sub-bottom profiling and targeted underwater excavation to identify and investigate buried lacustrine and fluvial features within Walker Lake. I then combined data from underwater investigations, cutbank records from the Walker River channel, and an auger profile from the northern edge of Walker Lake to address questions about lake stability. Combined with tephra and radiocarbon analyses, these data helped to clarify the history of the lake, develop a more nuanced lake-level curve for the latest Holocene, and address questions about mechanisms for lake level changes. Finally, I combined floral and faunal materials collected during underwater investigations with cutbank data and the new lake curve to begin defining changes in the WLB environment during the last millennium.

3.1. The Walker Lake Basin: History and Previous Research

Walker Lake is a high-desert perennial lake located on the western edge of Nevada, situated between the Wassuk Range to the west and the Gillis Range to the east (Figure 3.1). Its current watershed is ~10,500 km^2 and its primary water source is the Walker River. Walker River includes two tributaries, the West Walker and East Walker branches. Their source is predominantly snowmelt from the Sierra Nevada Mountains, which flows into the lake from spring to mid-summer (Adams 2007; Beutal et al. 2001). For 140 years, Walker River has been artificially diverted for agricultural use, leading to drastic lake recession. In some years, such as 2014-2016, water divergence has been so great that the Walker River channel becomes completely dry before it reaches the lake (Adams 2007; Beutal et al. 2001). As a result, Walker Lake has receded from its historic highstand at 1,252 meters above sea level (masl) in 1868

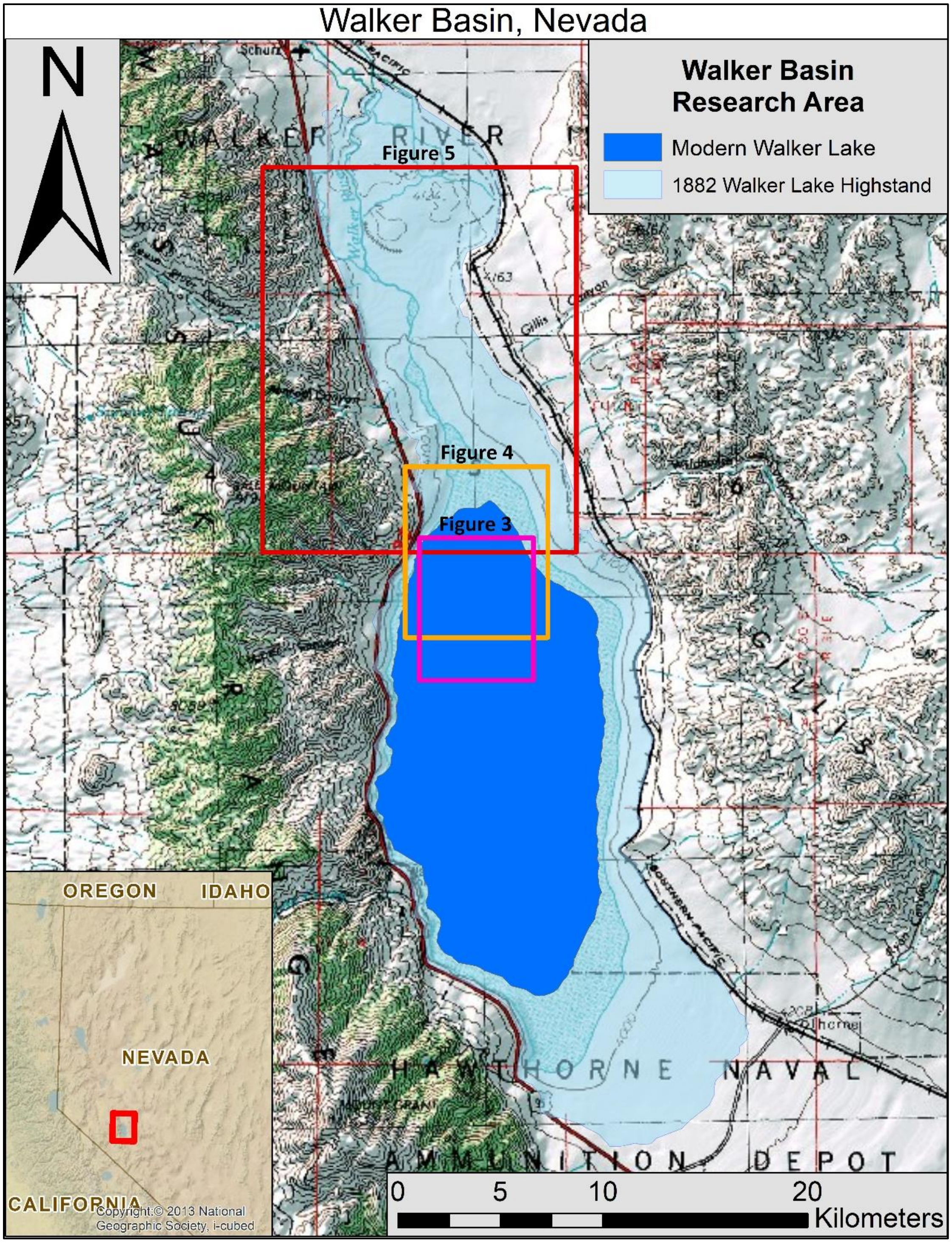

Figure 3.1. Location, historic high stand, and 2019 water level of Walker Lake, Nevada. Topographic base map (National Geographic Society 2013) and inset map (ESRI 2017) modified by author in ArcMap 10.6.

(Adams and Rhodes 2019b) to 1,245.4 masl in 1882 (Harding 1965) and to 1,194.01 masl in March 2019 (Figure 3.1)(Allander et al. 2009; Lakes Online 2019; Lopes and Smith 2007). Studies by Milne (1987; see also Benson et al. 1991) suggest that if water had not been diverted from Walker River the current lake level would be 1,253 ± 3 masl.

The historical changes to Walker Lake provide an observable record of the impact humans have had on the environment. Rapid decline in lake levels decimated the local fish population resulting in the extinction of the Walker Lake sub-species of Lahontan Trout (Beutel 2001; Gerstung 1988). Fish can no longer survive in the lake due to its increased salinity, a consequence predicted decades ago (Cooper and Koch 1984); therefore, the State of Nevada no longer stocks the lake with fish for anglers (Beutel 2001; Elliot 1995; Wurtsbaugh et al. 2017:820). Falling lake levels have also contributed to the slow economic decline of the nearby towns of Walker Lake and Hawthorne because their primary economic drivers, fishing, water recreation, and vacation activities, have ceased (Beutel et al. 2001). The US census shows that the populations of these communities are falling: the population of Mineral County went from 5,071 in 2000 to 4,772 in 2010, and to an estimated 2018 population of 4,514 (Census Viewer 2019; United States Census Bureau 2019). I observed these declines first-hand while conducting the research detailed below. Among various anecdotal observations, dead fish regularly washed ashore during the abnormally high Walker River flow of summer 2017, and multiple local businesses shuttered between the beginning of fieldwork in 2014 and end of fieldwork in 2017.

While it is clear that modern anthropogenic changes in lake level and river flow have had a negative impact on the WLB, studies in the region show that lake level and river flow changes are not unprecedented. Following the recovery of numerous cores from the lake in the late 1970s and early 1980s, multiple publications addressed lake-level history for the last 50,000 years (Benson 1988; Benson et al. 1990; Bradbury et al. 1989; Newton and Grossman 1988). These studies initially focused on Walker Lake in the context of pluvial Lake Lahontan, but were expanded to include its broader history from before 41,600 calendar years before present (cal BP) to the present. Research has since further expanded to include new proxy records and questions. Overall, the known history of Walker Lake has varying degrees of resolution depending on the proxy records used for reconstruction, the preservation of the records studied, and the success of record recovery (Benson 1988; Benson et al. 1990, 1991; Berelson et al. 2009; Bradbury et. al 1989; Newton and Grossman 1988; Petryshyn et al. 2012; Yuan et al. 2004, 2006a, 2006b).

Sediment cores recovered in the 1970s and 1980s were analyzed for changes in oxygen-18 isotope ratios ($\delta^{18}O$), pollen, diatoms, and crustacean species. Cores were dated using bulk carbon samples and combined with radiocarbon dates on shoreline tufas to reconstruct a history of Walker Lake from before 41,600 cal BP to the present (Benson 1988; Bradbury et al. 1989; Newton and Grossman 1988). Unfortunately, radiocarbon dates obtained on shoreline tufas and bulk carbon samples are highly problematic. Tufas are open systems that absorb carbon from their environment, and the specific material dated from bulk samples are unknown. As a result, dates from these materials increase the potential for inaccuracy and/or chronological uncertainty (MacDonald et al. 1991; Srdoč et al. 1986). With this in mind, the current chronology follows. The WLB appears to have maintained a slightly saline to freshwater lake before 34,000 cal BP. Benson and Thomson (1987) argue that by 43,500 cal BP Walker Lake fell to extreme lows or desiccation until ~17,000 cal BP. Conversely, Bradbury et al. (1989) argue that the ostracod record southeast of Walker Lake suggests it remained high until ~29,000 cal BP. Researchers agree that after this time Walker River likely diverted to the Carson Sink leading to a low, brackish lake throughout the last glacial maximum (Benson and Thompson 1987; Bradbury et al. 1989). Bradbury et al. (1989) claim the lake completely desiccated by ~18,000 cal BP until the mid-Holocene (~5,500 cal BP). In contrast, Benson and Thompson (1987) maintain the WLB was connected to greater Pleistocene Lake Lahontan between ~17,000 and 14,700 cal BP and therefore would have held a large lake at this time. Geological studies elsewhere in the Lahontan Basin, including landform studies and soil development reported by Adams and Wesnousky (1998), confirm Walker Lake formed the southern-most embayment of Lake Lahontan during the late Pleistocene. Lake Lahontan reached its Sehoo highstand, located at 1,338 masl, at ~13,100 radiocarbon years before present (^{14}C BP) or ~15,700 cal BP (Adams and Wesnousky 1998). At this time Walker Basin's lake was connected to greater Lake Lahontan through Adrian Gap (1,308 masl), south of the Carson Sink. Immediately after it reached the Sehoo highstand, climate change resulted in the lowering of the Lahontan system, separating it from the Walker Basin. At the same time, divergence of the Walker River from the WLB to the Carson Sink through the Adrian gap resulted in the rapid regression of Walker Lake (Adams and Rhodes 2019b; Adams and Wesnousky 1998, Benson 1988; Benson and Thompson 1987).

After the Sehoo highstand, the absence of preserved lake deposits and associated proxy records indicate Walker Lake receded to a shallow marsh or perhaps even a playa floor (Bradbury et al. 1989). It is worth noting, however, that the absence of evidence for lake levels between ~15,500-5,500 cal BP does not prove the absence of a lake during this time. Two major lake transgressions occurred across the western Great Basin after the 15,500 cal BP recession. These transgressions never surpassed the Adrian Gap, connecting Walker Lake to the rest of the greater Lahontan Basin, but they did surpass Astor Pass (1,224 masl) and reached Emerson Pass (1,202 masl) during the Younger Dryas (12,700-11,000 cal BP) and early Holocene (10,000-8,500 cal BP), respectively. These transgressions connected multiple Lahontan sub-basins, forming large pluvial lakes (Adams et al. 2008; Grayson 2011). In the eastern Great Basin, Lake Bonneville also transgressed during the Younger Dryas. During the early Holocene, flooding of the southern Bonneville sub-basin, Lake Gunnison, regularly connected it to the northern remnant of Lake Bonneville through the Old River Bed (Goebel et al. 2011; Grayson 2011; Madsen et al. 2015; Oviatt et al. 1992; Oviatt and Shroder 2016). Such lake transgressions across the Great Basin provide support for potential Walker Lake transgression during these times. Based on the gaps in the record and issues with sediment recovery from the early Walker Lake cores (Benson 1988), it is likely that lake-level history bracketed by the Sehoo and late mid-Holocene highstands (15,700-4,000 cal BP) is more complex than Bradbury et al. (1989) suggest. Unfortunately, without new proxy records containing materials from this period, the nature of the lake prior to 5,500 cal BP remains uncertain.

Paleolimnological records of Walker Lake from the late mid-Holocene to the present provide multiple lines of evidence for periods of lake-level rise and fall (Figure 3.2). Lake level rapidly rose beginning 5,500 cal BP and reached a highstand at 1,244 masl by ~ 5,100 cal BP (Adams 2007; Benson and Thompson 1987; Bradbury et al. 1989). This rise was likely the result of the Walker River diverging from the Carson Sink back into the WLB (Adams 2007; Adams and Rhodes 2019b; Benson et al. 1991; Bradbury et al. 1989). After lake resurgence, Adams and Rhodes (2019b) report fluctuations in highstands between 1,245 and 1,262 masl at 4,000-3,200 cal BP. Lake level dropped to 1242 masl around 2,900 cal BP, followed by a rise to 1257 masl at 2,750 cal BP. This was followed by desiccation to a saline marsh that did not fully recover to 1,247 masl until 1,500 cal BP (Adams 2007; Adams and Rhodes 2019b; Benson and Thompson 1988; Benson et al. 1991; Bradbury et al. 1989). Based on magnetic susceptibility, total inorganic carbon, and $\delta^{18}O$ data, the age range of this desiccation event as reported by Yuan et al. (2006b) was slightly older, from 2,700-2,400 cal BP. After the 1,500 cal BP highstand, late-Holocene recessions occurred from 1,500-1,000, 960-700, and 500-300 cal BP, with previous research suggesting these lowstands reached an elevation range of 1,224-1,200 masl (Adams 2007; Adams and Rhodes 2019b; Benson and Thompson 1987). After 300 cal BP Walker Lake rose to its historic highstand at 1,252 masl until the rapid desiccation of the last century and a half began.

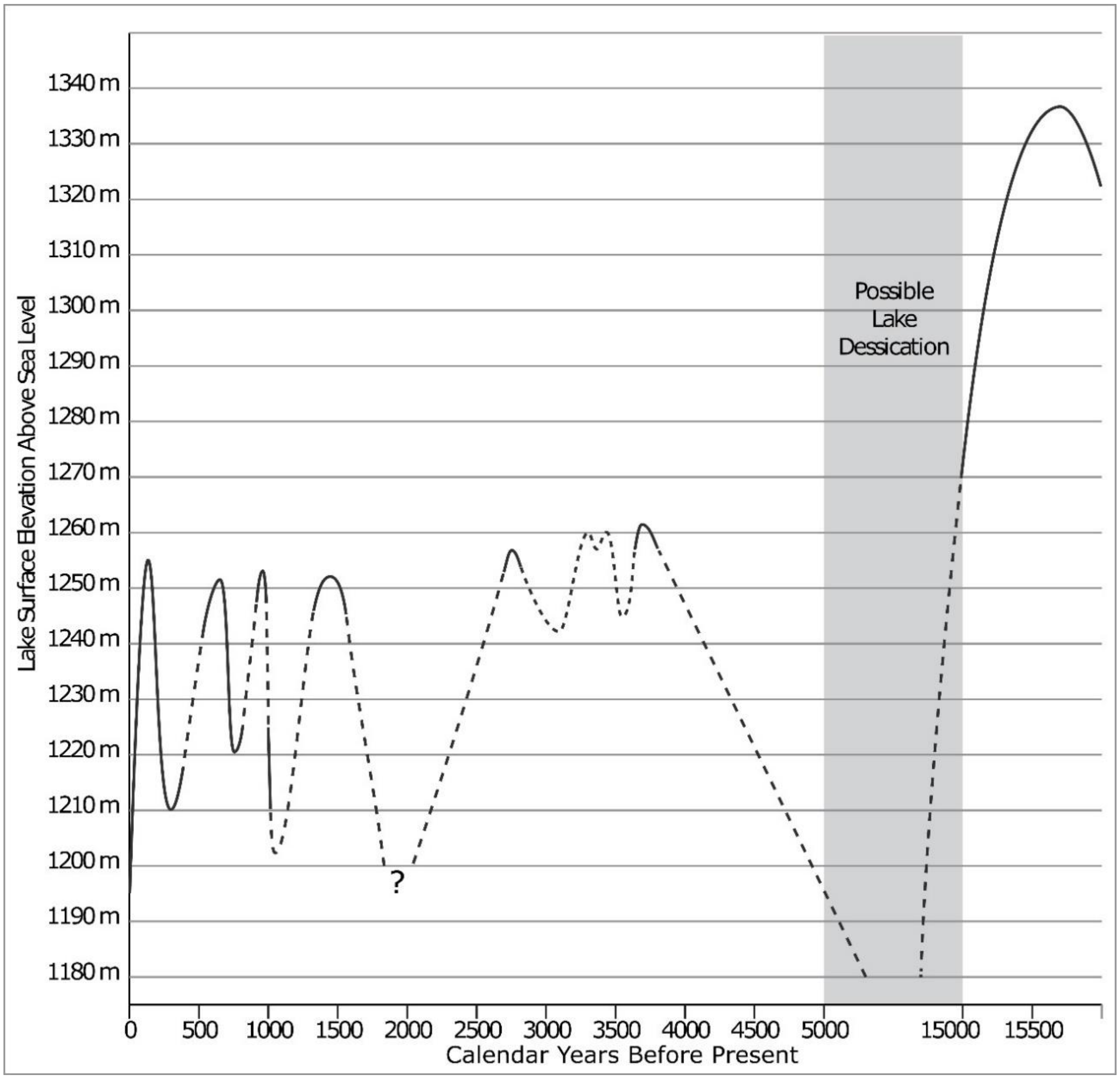

Figure 3.2. Lake curve presented by Adams (2007) and Adams and Rhodes (2019b) for Walker Lake. Image adapted from Adams and Rhodes (2019b:Figure 4).

The general pattern of lake-level change discussed above is supported by $\delta^{18}O$ records presented in Yuan et al. (2004, 2006a, 2006b), with the only minor difference being an early date for the third-millennium recession. This difference may be due to the resolution of the different proxy records used (Adams 2007). Other proxy-record studies, such as measuring and dating Walker Basin tufa deposits (Newton and Grossman 1988), identifying historic levels of carbon-associated sulfate (Berelson et al. 2009), and measuring the rate of stromatolite lamination (Petryshyn et al. 2012), generally agree with the established chronology.

The cause of the fluctuations observed in lake levels has been debated between climate change and divergence of the Walker River to the Carson Sink. After King (1978) identified the Walker River paleochannel in Adrian Valley where, at times, the river flowed into the Carson Sink, multiple researchers attributed periods of significantly low Walker Lake levels to Walker River diversion (Benson and Thompson 1987; Benson et al. 1991; Adams 2007). Despite this assertion, the timing of these river avulsions is poorly understood. King (1993, 1996) identified river diversion in Adrian Valley as late as 385 cal BP. More recently, Adams and Rhodes (2019b) detailed paleochannel deposits at the Perazzo Slough site in Mason Valley near the modern Walker River channel that indicate Walker River flowed north to the Carson Sink multiple times between 1,520 and 930 cal BP. Similarly, they described paleochannel deposits at the confluence between Adrian Valley and the Carson River that suggest the Walker River flowed north multiple times during the last 1,000 years. Adams and Rhodes acknowledge, however, that these deposits could have been created by meanders in the Carson River. While evidence for Walker River diversion north through Adrian Gap is growing, more research clarifying the mechanism and timing for diversions is needed.

In addition to the impact of possible river diversion, multiple researchers attribute some Holocene lake-level shifts to regional climate change based on local climate models and proxy records (Bradbury et al. 1989, Hatchet et al. 2015, Newton and Grossman 1988, Yuan et al. 2004, 2006b). In particular, Hatchet (2015) focused on climate conditions during the Medieval Climate Anomaly (MCA) (1,150-700 cal BP) to model low lake levels before and after a wet period dating to 879-829 cal BP (Cook et al. 2010). Adams and Rhodes (2019b) argue against these assertions. They combine tree-ring data, river gauge information, and climatic models to estimate lake levels based on modeled waterflow to the basin. Their model indicates that after 2,000 cal BP Walker Lake should not have fallen below 1,245 masl, whereas the lake-level record shows that the lake fell to 1,220 masl or lower at least three times during the last 2,000 years. As a result, they maintain that every major recession after 2,000 cal BP (i.e., at 1,050, 900, and 300 cal BP) was primarily driven by Walker River diversion to the Carson Sink. The model suggests, however, that local climate change and drought conditions could have led to a major lake recession even without river diversion from 2,500-2,000 cal BP.

The current lake-level chronology was developed over decades using various datasets to estimate elevations and dates. Each approach is useful but results in holes that can be filled with additional studies. For example, the earliest cores contained large gaps in the sediment record that may be filled with higher-resolution sampling (Benson 1988). Similarly, $\delta^{18}O$ studies first performed by Benson (1988) were continued by Yuan et al. (2004, 2006a, 2006b), who collected new cores with higher resolution, but lacked stratigraphic data to determine the elevation of the lake during highstands and lowstands

(Adams 2007). Adams (2007) and Adams and Rhodes (2019b) provide strong data for lake-level changes. They focus on stratigraphic profiles and shoreline features above the contemporary lake level to identify highstands. However, features preserved below today's lake level were not used to inform their interpretations. Instead, Adams and Rhodes (2019b) relied on models estimating river flow and climate during the Holocene to determine lowstand elevations. In this study, I combine data from both above and below the modern water line to refine the geological and environmental history of Walker Lake and assess the concept of river diversions versus climate as a trigger for late Holocene fluctuations.

3.2. Methodology

The dataset presented below was acquired over four field seasons which produced sub-bottom remote sensing profiles, materials from underwater test excavations, core sediment analyses from the underwater excavation blocks, and records of the river cutbanks. Combining these methods improves the interpretive resolution of the WLB record.

3.2.1. Sub-Bottom Survey

To identify evidence for preserved lake-lowstand or fluvial features buried underwater in Walker Lake, I collected sub-bottom acoustic data during summer 2017 across the northern portion of the lake (Puckett 2020). The survey was undertaken from a 16-foot, flat-bottomed fishing boat powered by a 25-HP Mercury outboard motor. The sub-bottom equipment consisted of a Teledyne Benthos 665 topside unit with a TTV-170 towfish situated ~2 m below the water surface. The data from the system was recorded on a laptop running Chesapeake Technology's Sonarwiz 7.0. Positioning was collected using a Hemisphere Atlaslink GNSS Smart Antenna GPS unit, and continuous location information was recorded during sub-bottom data collection. All sub-bottom data has sub-meter-accuracy location information. Specifics of the sub-bottom survey area and pattern used to collect data are presented in Puckett (2020) (Figure 3.3). Generally, sub-bottom survey was performed across a deltaic rise at the north end of the lake, identified by consulting published bathymetric data (Lopes and Smith 2007) (Figure 1.1). This area was selected to look for potential fluvial or lacustrine features and sediments deposited on or in the deltaic sediments. Additionally, a water depth of 9-11 m was targeted because we expected depths ~10 m to have thinner lacustrine deposits covering preserved features than would water depths shallower than 10 m. Lake bottom depths below 11 m were avoided to maximize the time divers could work while investigating and excavating any features observed in the sub-bottom profiles.

Well established standards for sub-bottom profiler analysis and interpretation were used to review the data (Caiti et al. 2006; Grøn and Boldreel 2013). I noted visibly distinct reflections, highlighted the precise locations and depths of preserved geomorphic features, and identified areas for test excavation and coring to further explore drowned and buried landforms later in the field season. All locational data were entered into ArcMap 10.4 to correlate features observed during remote sensing with spatial data collected during the field seasons.

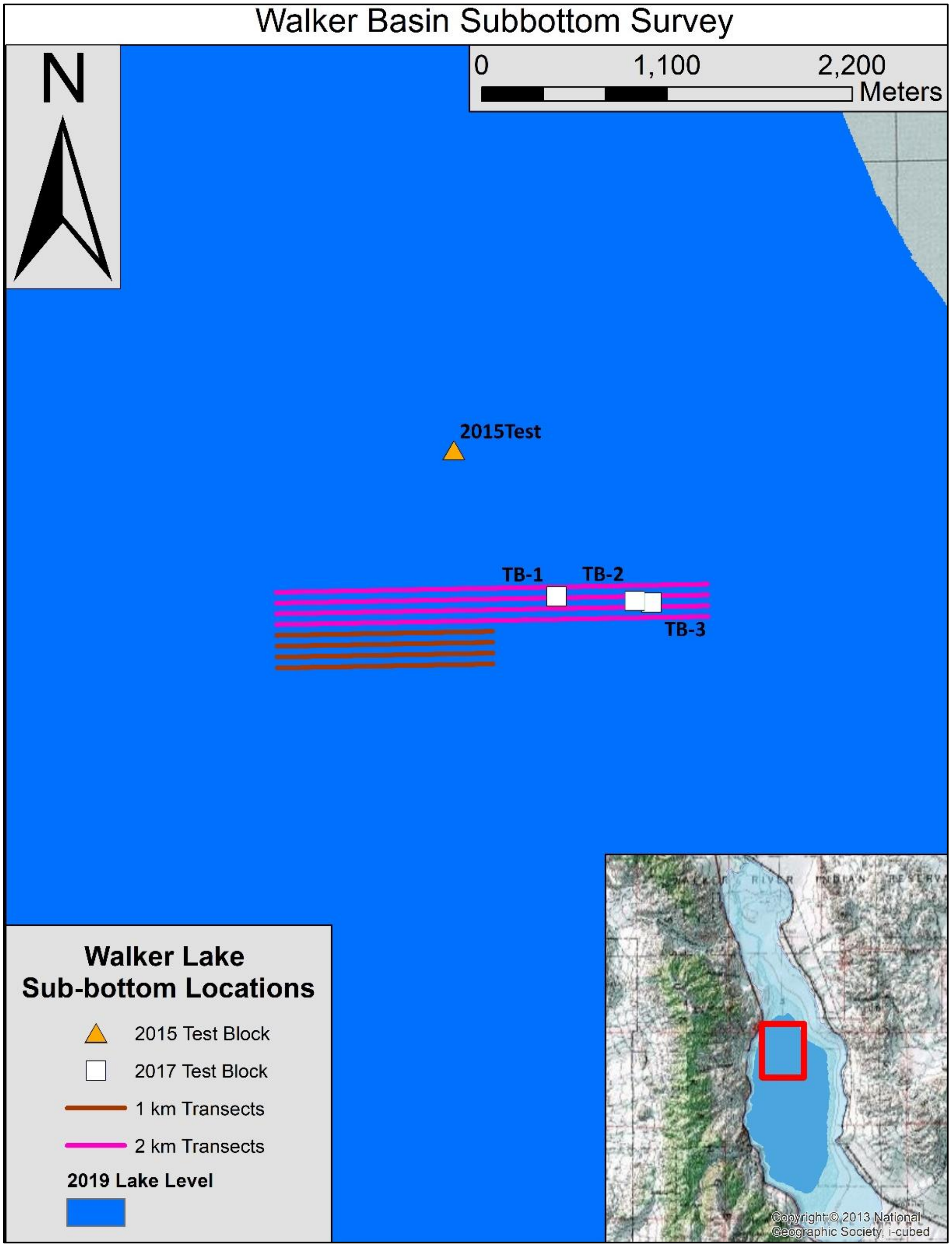

Figure 3.3. Sub-bottom survey transects discussed in the text in relationship to the test blocks excavated in 2015 and 2017. Note that sub-bottom transects are numbered from south (Transect 1) to north (Transect 8). Topographic base map (National Geographic Society 2013) and Walker Lake DEM data (Lopes and Smith 2007) were modified by author in ArcMap 10.6.

3.2.2. Test Block Excavation and Coring

To assess underwater excavation methodologies, acquire preliminary sediment data, and collect an initial core from the lake, we excavated a first test block (2015Test) in summer 2015, placing it at the northern end of the lake. I used USGS bathymetric data collected in 2005 (Lopes and Smith 2007) to narrow the placement location to an area with minimal slope representing a broad, flat, submerged landscape. The test block measured 2 m north-to-south by 1 m east-to-west and was delineated by an aluminum frame anchored to the lake bottom with 3-m-long galvanized steel conduit. All elevation measurements were recorded from the frame, which provided a consistent point of reference. All below-surface measurements were identified relative to the northeast corner of the test block. Excavation of the block was performed with trowels and proceeded in 10-cm arbitrary levels. All excavated sediment was collected with a 4-inch water dredge powered by a 10-hp water pump. Sediments were sieved through nested 1/4-inch, 1/8-inch, and 1/16-inch screens. During excavation, zero-visibility conditions were constant due to silts and clays in the water column. Visibility conditions were not improved with the use of lights. We relied on the sound and feel of trowel use to identify changes in stratigraphy. All observations of screened paleoecological materials were made in the field and from in-field level forms. The descriptions of the 2015 sediment core were also made in the field on wet sediments.

To identify the sediments noted in the reflections in the sub-bottom profiles and to verify interpretations of these data, we excavated three additional 2-x-1-m test blocks in Summer 2017 and collected cores from each. These blocks were placed at the north

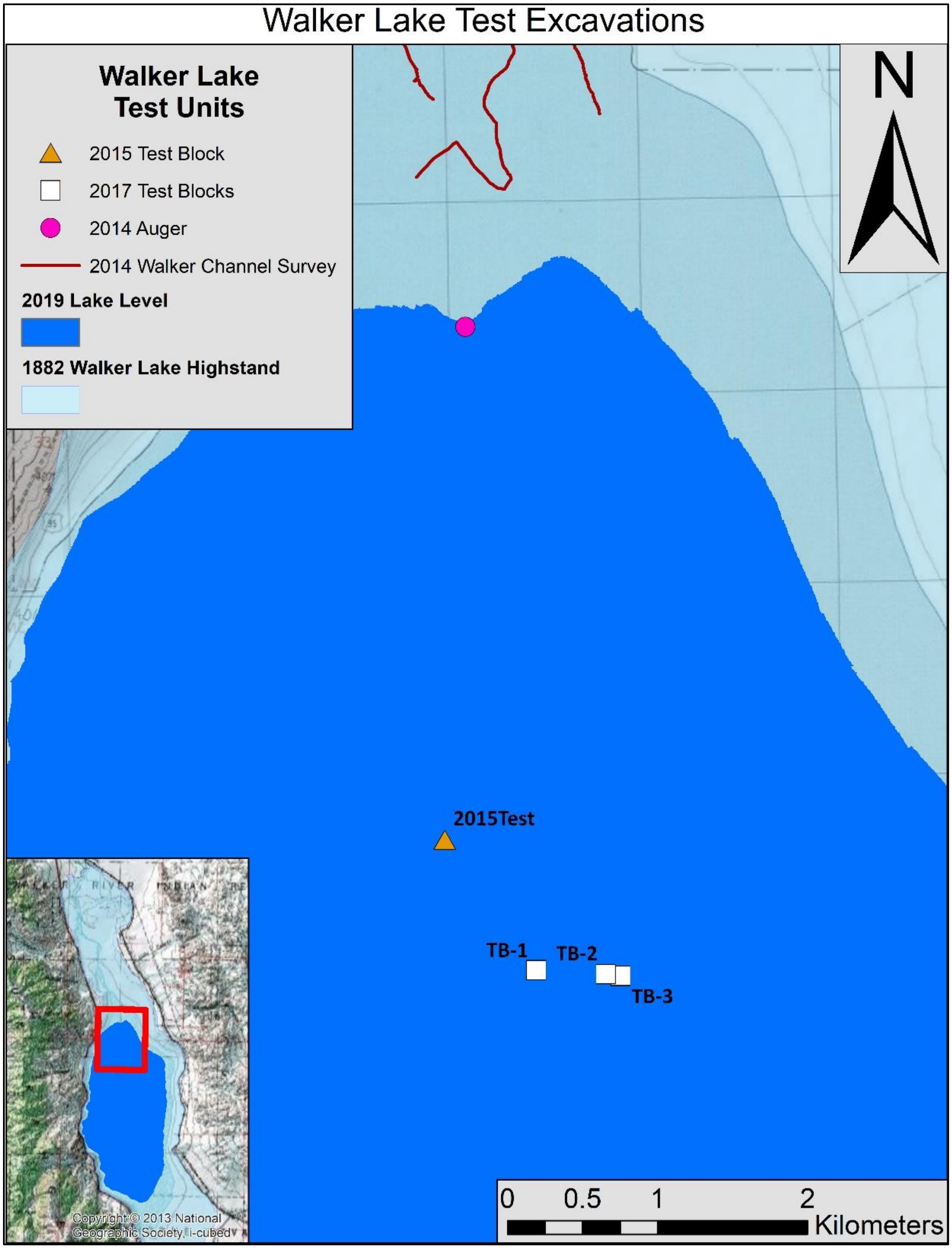

Figure 3.4. Location of the 2015 and 2017 excavation test blocks relative to 2019 water levels. Topographic basemap (National Geographic Society 2013) and Walker Lake DEM data (Lopes and Smith 2007) were modified by author in ArcMap 10.6.

end of Walker Lake. The block locations were selected to target specific reflections and subsurface features identified during sub-bottom data examination, with two features ultimately selected: Features 1 and 3 (see sub-bottom results below). I placed Test Block 1 (TB-1) east of Feature 1 at a stratigraphic high point, Test Block 2 (TB-2) on the western edge of Feature 3, and Test Block 3 (TB-3) on the eastern edge of Feature 3 (Figure 3.4). Excavation of these test blocks proceeded with the same methodology used in 2015 save one difference: we collected all ecological materials found in the screens for later analysis. To avoid hazards to divers from potential inundated sediment collapses, excavations were limited to a depth of 2 m. Once each block was excavated to 2 m, I attempted to record the stratigraphy. Unfortunately, fine-grained sediments obscured visibility, creating blackout conditions and making stratigraphic observations impossible underwater. To mitigate this limitation, cores were collected from each block to later record the stratigraphy in the lab.

Aluminum tubes with 7.6 cm diameters were used to collect each sediment core. In 2015 a core was placed in the northeast corner of the test block before excavation and driven into the sediment with a hammer. We removed this core after excavation ended and cut and recorded it in the field to obtain a general understanding of the test block sediments. To obtain a full record of excavated and below excavation sediments in 2017, we recovered two to three cores from each text block. To ensure we recovered a sample of the upper sediments excavated, the first core from each block was placed in the northeast corner prior to sediment excavation. To guarantee we collected sediment for the bottom half of each excavation block, the second core was placed in the southwest corner at 1-m depth below the aluminum excavation frame (BF) (in TB-2 the second core was placed at the midpoint along the southern excavation wall). Finally, to capture sediments below the excavation block, we drove a third core into the center of TB-2 and TB-3 once excavation reached 2.0 and 2.1 m BF depth, respectively. Every core was hammered into the sediment as far as they could go. After excavation was completed, the cores were capped and taped to seal the top of the tube. They were then removed from the sediment using airlift bags. Once the bottom of each core was exposed, it was capped and taped prior to being brought to the surface. In total, we collected nine cores, one from 2015Test, two from TB-1, three from TB-2, and three from TB-3.

Cores collected in 2017 were taken to the Geoarchaeology Laboratory at Florida State University for cutting and analysis. I cut each core using a custom-made saw cart and jig. Half of each core was wrapped in plastic and stored for future analyses. The split cores from each test block were laid next to one another for visual, elevation, and relative stratigraphic comparisons. I described the stratigraphy in each core using "texture by feel" analysis, standard stratigraphic descriptors (Schoeneberger et al. 2012), Munsell coloring, and depth measurements. I completed Munsell coloring on dried sediments, meaning the colors are often lighter than the same sediments observed underwater. This was beneficial, however, because the dried sediments allowed for subtle differences in depositional context to be more easily identified. Unfortunately, the limited width of the sediments recovered in the cores made it impossible to accurately describe their structure and consistency. Once descriptions were completed, I preserved the analyzed core halves for future work.

3.2.3. In-Field Cutbank Observations and Augering

To record evidence of depositional changes and environmental fluctuation across the lower Walker Lake basin, during the summers of 2014 and 2016 field crews surveyed the lower portion of the Walker River channel from 15.8 km north of the lake to the 2014 lake margin (Figure 3.5). We looked for intact stratigraphic records of stable landforms, abrupt contacts indicative of lake-level change, and/or the presence of organic remains, charcoal, and any archaeological materials (Puckett 2020). We observed no archaeological materials, but recorded multiple cutbanks with evidence of burn events, lake transgressions and recessions, and tephra marker horizons. Cutbanks were recorded by detailing a representative column profile of the observed stratigraphy and recording a GPS-location point. Elevations were measured below the surface (BS) of each cutbank, and a thorough description, including "texture by feel" analysis (Schoeneberger et al. 2012), was recorded for each sedimentary package. Additionally, a single 7.6 cm auger hole was excavated at the northern extent of Walker Lake in 2014 to record the sediments preserved near the river/lake confluence (Figure 3.5). We recorded the sediment from this auger in 25-cm increments to a depth of 3.75 m BS.

3.2.4. Tephra Analysis

The western Great Basin is a volcanic rich area with abundant evidence for repeated volcanic events throughout history (Grayson 2011). The region around the Walker Lake basin is no exception. The Mono Basin, 65 km south-southwest of Walker Lake has been subject to regular volcanic events over the last four million years, and the

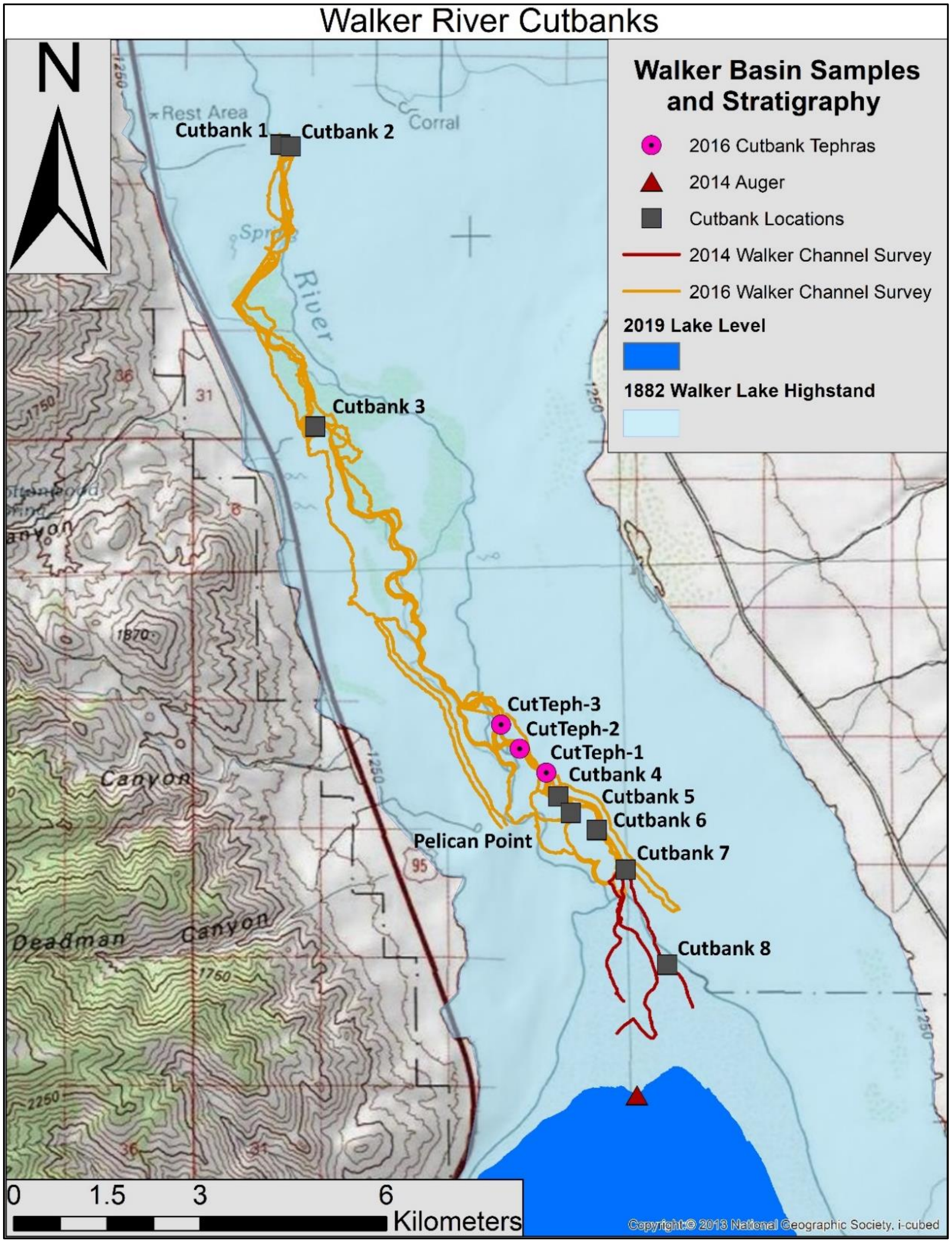

Figure 3.5. Location of Walker River channel surveys, collection locations of tephra samples, and the locations of cutbanks and augering described in the text. Topographic base map (National Geographic Society 2013) was modified by author in ArcMap 10.6.

Wilson Creek Formation documents eruptions in the region between 62,000 and 12,500 cal BP (Marcaida et al. 2014). Research from the Mono-Inyo Craters just south of Mono Lake document more recent eruptions. The South Mono Eruption occurred at 1325 cal BP (Bursik et al. 2014), and the North Mono Eruption occurred at 650 cal BP (Sieh and Bursik 1986). Ash from both events has been documented within the Walker Lake basin, and Bursik et al. (2014) clarify that no volcanic events took place near the Mono and Walker Basins between the South and North Mono eruptions. With abundant evidence of nearby volcanic activity, identifying and studying tephra material from the Walker Basin is valuable for informing lake and environmental chronology.

During this research I collected six tephra samples, three from Walker River cutbanks where clean and easily accessible deposits were identified, and three from test block cores. Cutbank tephra samples were all located south of cutbank 3, ~430-1500 m north of cutbank 4, and were designated CutTeph-1, CutTeph-2, and CutTeph-3 (Figure 3.5). I did not collect tephra samples from the cutbanks detailed herein due to the ephemeral and patchy tephra material within cutbanks 1-8. Conversely, locations containing clean, accessible tephra samples did not preserve extensive evidence for lake-level changes or different depositional environments, providing minimal information about the associated depositional sequences. Nonetheless, field observations showed each sample collected was deposited between fine-grained sediments <1 m from the cutbank surface and were in similar depositional contexts, providing strong stratigraphic correlation to the cutbank 1-8 tephras. More specifically, the cutbank tephra analyzed below (CutTeph-3) was deposited at a depth of ~70 cm BS between two fine-grained

Figure 3.6. Stratigraphic profile of sediments associated with tephra sample CutTeph-3 visible as the white band of sediment in the profile.

sediment packages indicative of low-energy, deep-water depositional environments. Above the upper fine-grained sediments were one gravelly sand and one massive sand package capped by a blocky silt loam at the surface (Figure 3.6). This sequence suggests at least one, and perhaps two lake-recession events post-date the deposition of CutTeph-3.

For each cutbank tephra sample, a GPS location was recorded along with its depth below surface in the cutbank profile. I collected each sample with a clean margin trowel from the center of the tephra stratums and placed them in 3-x-5-inch geological sample bags labeled with the tephra designations. I took photographs of each location and the corresponding stratigraphic profile.

Test-block core samples were collected from TB-1: northeast core**,** TB-2: south core, and TB-3: southwest core. After these cores were cut, I collected each sample in the lab from the center of the tephra deposits in an undisturbed half of the core. Each sample area was photographed prior to collection, samples were cut from the cores with a clean margin trowel, and they were placed in 3-x-5-inch geologic sample bags.

Tephras were sent to the Concord University Electron Microprobe Facility and Tephra Lab for analysis by Dr. Stephen Kuehn. Four of the six samples were studied: a single cutbank sample (CutTeph-3) and all three test-block core samples. I selected these samples to determine if the submerged tephras in the lake provided stratigraphic correlation between the excavation block locations and the tephras identified in the cutbank profiles.

In the lab, each of the four tephra samples was sieved and separated from non-volcanic materials. Glass separates were mounted for high precision electron-probe microanalysis (EPMA). Images of the glass separates are shown in Appendix B (Figures B.1 to B.4). Recommendations and general methodology for EPMA are detailed in Kuehn et al. (2011) and Lowe et al. (2017). Eighty-nine total samples were taken from the tephras with beam settings at 15 kV, 40nA, and a 15-micron target diameter. Three reference materials were used for sampling and testing control: BHVO-2G, NKT-1G, and the Lipari obsidian. Spectrometer results were obtained for a suite of elements detailed in Appendix B (Tables B.1-B.8). These are reported as both raw numbers and normalized values accounting for halogens (Kuehn et al. 2011).

3.2.5. Radiocarbon Dating

I selected radiocarbon samples from specific stratigraphic units within the cores, targeting strata that could provide comparisons of the age of stratigraphic layers between and within the test blocks. In particular, I elected to sample the lower sandy layers to date the deposition of these high-energy sediments, especially because these would represent locations that were littoral to the lake and not deeply submerged during deposition. The strata selected were carefully searched for short-lived organic material such as small twigs, seeds, or fish. No charcoal was identified *in situ* in these sandy deposits. I primarily selected woody terrestrial materials for dating, though in one case a seed and in another a fish bone were also selected. While no sample taxa were identified, their small size and structure (e.g., complete twigs, seeds) indicated they were from short-lived woody shrubs (the exception was sample PSU-4948, which was from a larger wood fragment). Each sample was recorded with its depth, a visual material description, and the associated stratigraphic unit.

These samples, once collected, were kept in refrigeration until they could be sent to the Penn State Radiocarbon Laboratory for dating. Wood samples were prepared, pretreated, and processed following methods detailed in Kennett et al. (2014). Minor methodological differences include the use of OX-II primary standards and a Prophet River Wood background. The bone sample was prepared, pretreated, and processed using the methods detailed in Narasimhan et al. (2019), though solvent washes were not used because the bone was recently recovered from a core. All results were corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977), with $\delta^{13}C$ values measured on prepared graphite using the AMS. I calibrated the radiocarbon dates using the Intcal20 curve in the online version of OxCal 4.4 (Ramsey 2020; Reimer et al. 2020). For the fish bone, a 300-year standard reservoir effect for Walker Lake (Benson et al. 1991; Broecker and Walton 1959; Yuan et al. 2006b) was entered into the OxCal 4.4 program under the curve options. This applied the 300-year reservoir effect to the returned calibration.

Finally, I ran a stratigraphic Bayesian model using OxCal 4.4 to identify the depositional periods associated with each of the radiocarbon dates and their stratigraphic deposits. Nine of the ten radiocarbon dates were used to model the deposition of the coarse-grained sediments near the bottom of the cores. I embedded the entire series of dates into a sequence so the different stratigraphic components would be compared from oldest to youngest. I also bracketed each phase with boundary commands to model the beginning and end of their deposition. The first phase modeled was for the fish bone date collected from TB-1, stratum Ia. Because this date was collected from a lowstand elevation, I used “before” and “after” commands to constrain the phase boundaries by the dates of lake highstands occurring before and after this date (i.e., 2700 and 1500 cal BP; see Adams and Rhodes 2019b). Because the rest of the dates come from another lowstand setting and post-date the highstand at 960 cal BP, I used the “after” command to constrain the rest of the model to after 960 cal BP (Adams and Rhodes 2019b). The dates collected from TB-2, stratum II and TB-3, strata I and IIIc were combined into a single phase: these dates all overlapped at two sigma (σ). Within this phase, I created internal organization allowing for stratigraphic differences between the blocks. The TB-2:II dates were combined into one sub-phase that treated the dates as contemporaneous. The TB-3:I and IIIa dates were combined into a sequence that considered the stratum I date as occurring before the stratum IIIa dates. Finally, I combined the last two dates from TB-3 stratum IIIc into a final phase. Because all of the radiocarbon samples were collected below the tephra samples, the tephras maintain geochemical homogeneity, and they stratigraphically correlated to the North Mono tephra (see tephra analysis discussion below), I used a final "before" command to constrain the entire model to before the North Mono Eruptions at 650 cal BP (Bursik et al. 2014; Sieh and Bursik 1986).

3.3. Results: Walker Lake Data 2014-2017

3.3.1. Sub-Bottom Stratigraphy and Geomorphology

Sub-bottom profiles were numbered Transect 1 through 8 with Transect 1 at the southernmost position and Transect 8 in the northernmost position (Figure 3.3). In the profiles depicted below, transect 7 is shown and the view is to the north. The general profile signature includes the sediment surface reflection at a water depth of ~9.5-11 m, with the southern transects in deeper water and the northernmost transects being shallower. Below the surface, a series of reflections ranging from white to black in color show deposits with differential densities and texture. These are discussed below in further detail along with a number of anomalies evidencing possible changes in depositional environment. This discussion is based on standard methods for interpreting the depositional context of reflections and buried features identified using acoustic profilers (Caiti et al. 2006; Faught 2014; Faught and Flemming 2008; Grøn and Boldreel 2013; Lafferty et al. 2006; Wunderlich et al. 2005).

The upper portion of the sub-bottom profiles consists of reflections extending from the surface to a depth of 2.5 m BS (Figure 3.7; note these deposits extend to a depth of 4 m BS at the western end of the profiles associated with Feature 1). These reflections, ranging in color from white to black, run parallel to the lake bottom. Though

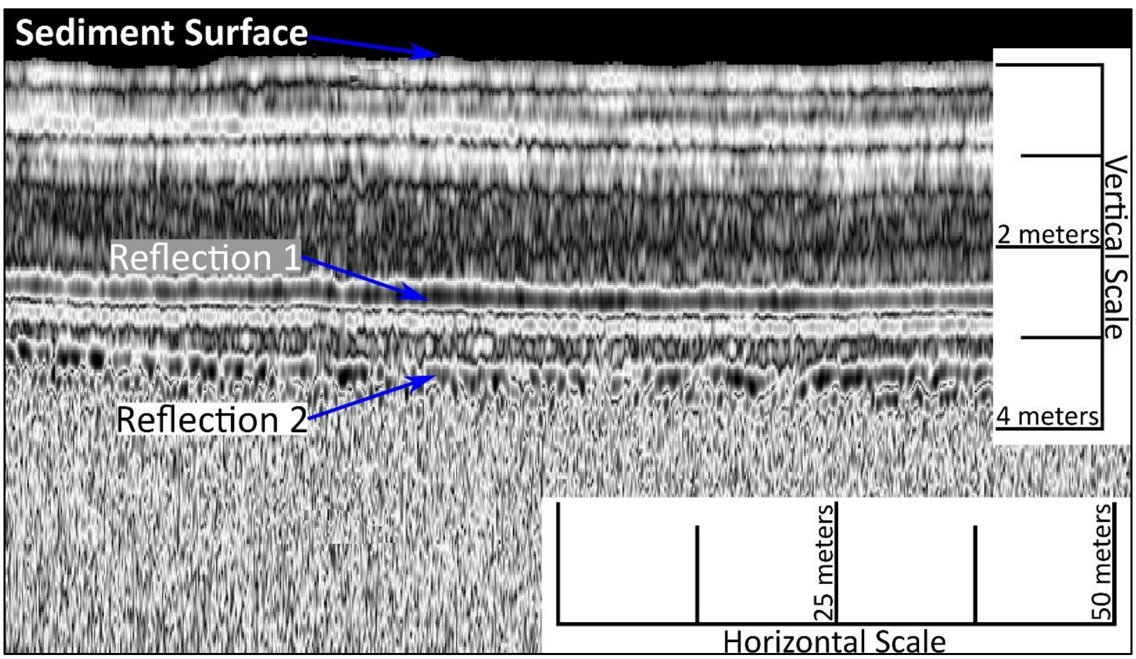

Figure 3.7. General distribution of strata observed in the sub-bottom profiles. All image views are to the north.

the presence of different densities within this portion of the profile indicates either changes in depositional context or post-depositional alteration of the sediments, the distribution and shape of the reflections suggests overall stable depositional energies and environments. The absence of anomalies observed in association with these reflections further evidences a stable depositional environment. Since these reflections extend from the sediment surface, it is likely that they represent consistent deep water lake sediment deposition. As the goal of this survey was to identify anomalies and features indicative of low lake levels and non-deep-water depositional conditions, the upper reflections were not labeled and are not discussed in further detail.

Below the upper 2.5 m of parallel reflections is a bright, ~30-cm-thick reflection (Reflection 1; see Figure 3.7). The visually distinct nature of Reflection 1, including upper and lower banding and internal coloration, suggests it may represent both a change in density and texture relative to the upper reflections. More importantly, observations of the reflection across the profiles show that it does not consistently run parallel to the surface. The anomalous shape and bedding pattern suggests it represents a different depositional environment from the sediments above. Extending approximately 50 cm below Reflection 1, two additional reflections generally run parallel to Reflection 1 or to the lake floor. As such, they may represent similar depositional environments to the upper 2.5 m of the sub-bottom profiles. Whatever their exact nature, these reflections are distinct in the profile from Reflection 1. Below them, at a depth of 3.5 m BS, is another reflection with a shape and pattern distinct from both the sediment surface and Reflection 1. This reflection (Reflection 2; see Figure 3.7) is dark, discontinuous, and undulating, suggesting some possible erosion and a depositional environment distinct from both the current deep-water environment and the context(s) that deposited Reflection 1. Reflection 2 is associated with a number of anomalies that provide evidence for low-lake levels. Below Reflection 2 is a relatively homogeneous signal with no clear changes in deposits save some faint deeply buried reflections, discussed further below. This homogeneous signal may represent deeper lacustrine sediments, though without clear bedding this remains conjecture. Combined, the sub-bottom reflections appear to represent five distinct sediment packages with unique depositional environments.

The first anomalous feature identified within the sub-bottom profiles is a rise in the depth of Reflection 1 from west to east across a distance of between 380-500 m, depending on the transect observed. This rise, labeled Feature 1, is shown in Figure 3.8 where Reflection 1 rises 1.44 m from a depth of 1,178 masl to 1,179.44 masl across a distance of 380 m, giving it a slope of 0.281 degrees. Reflection 2 generally parallels Reflection 1 across Feature 1, though Reflection 2 is more ephemeral, tends to have more undulations, and has a steeper slope at the eastern edge. The sub-bottom profiles indicate that Reflections 1 and 2 represent subsequent deposition events associated with Feature 1. Based on their shape, the deposits appear to be draped across a prograding delta that is spreading outward from the Walker River inlet east and north of the feature (Adams 2007). A similar deltaic feature is currently visible in the northern lake bathymetry (Figure 1.1). Based on the distribution and visually distinct nature of Reflections 1 and 2, it is possible that these represent sand deposits. If so, the higher energy required to deposit 20-30 cm of sand each for Reflection 1 and 2 across Feature 1 would indicate a lake transgression cycle. Under this model, the Reflection 1 and 2 deposits across Feature 1 represent two distinct lake transgression events during which sands were deposited at steadily higher elevations until the lake eventually rose well above the delta, burying the material in low-energy, deep-water sediments.

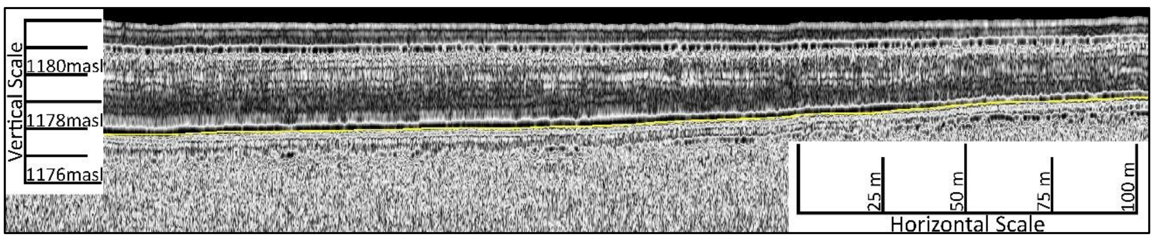

Figure 3.8. Feature 1 shown in Reflection 1 with the yellow line. Image is from sub-bottom profile Transect 7.

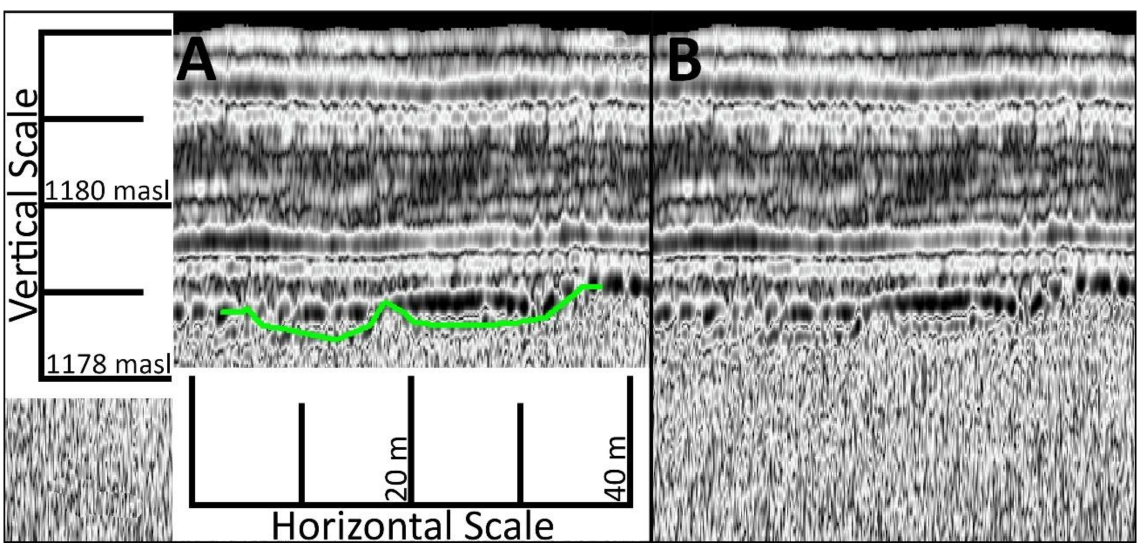

Figure 3.9. Feature 2 from Transect 7. A: Green line represents channel undulations below Reflection 2. B: Profile without Feature 2 highlighted.

The second clear feature discussed (Feature 2) is located ~850-900 m east of the western edges of the transects and consists of a small, shallow dip in Reflection 2 (Figure 3.9). Here, Reflection 2 abruptly dips ~50 cm across a distance of ~25 m. This dip is observed near the eastern edge of transects 1-3 and just east of the center of transects 5-8. The consistent easting of Feature 2 across 7 transects suggests it runs north-south. This factor, combined with the fact that Reflection 2 abruptly dips into the material represented by the homogenous reflection below Reflection 2, suggests Feature 2 represents a fluvial channel infilled by Reflection 2 material. The last feature discussed, Feature 3, represents a similar, deeper dip in Reflection 2. Located ~250-400 m west of the eastern edges of transects 5-8 with upper elevations at ~1,179.5 masl and a low depth of 1,177.6 masl (Figure 3.10), the feature expression moves eastward from north to south, and it is more pronounced and deeper to the north. Like Feature 2, Feature 3 is a dip in Reflection 2, extending as deep as 1.5 m into the reflection below. It likely represents the deposition of Reflection 2 sediments within sediments eroded by fluvial downcutting. Unlike Feature 2, however, all of the Feature 3 reflections above Reflection 2 also dip, albeit less extensively. This can be interpreted as gradual channel infill, a process observed in multiple abandoned channels north of Walker Lake. The spatial relationship between Features 1, 2, and 3 is shown in Figure 3.11.

Finally, near the western and eastern edges of all transects, and sometimes extending across much of the entire profile (e.g. transects 3 and 4), possible reflections are buried below Reflection 2 at depths of 7-12 m BS. These tend to be ephemeral and linear, but some may show dipping or downcutting indicative of preserved, deeply

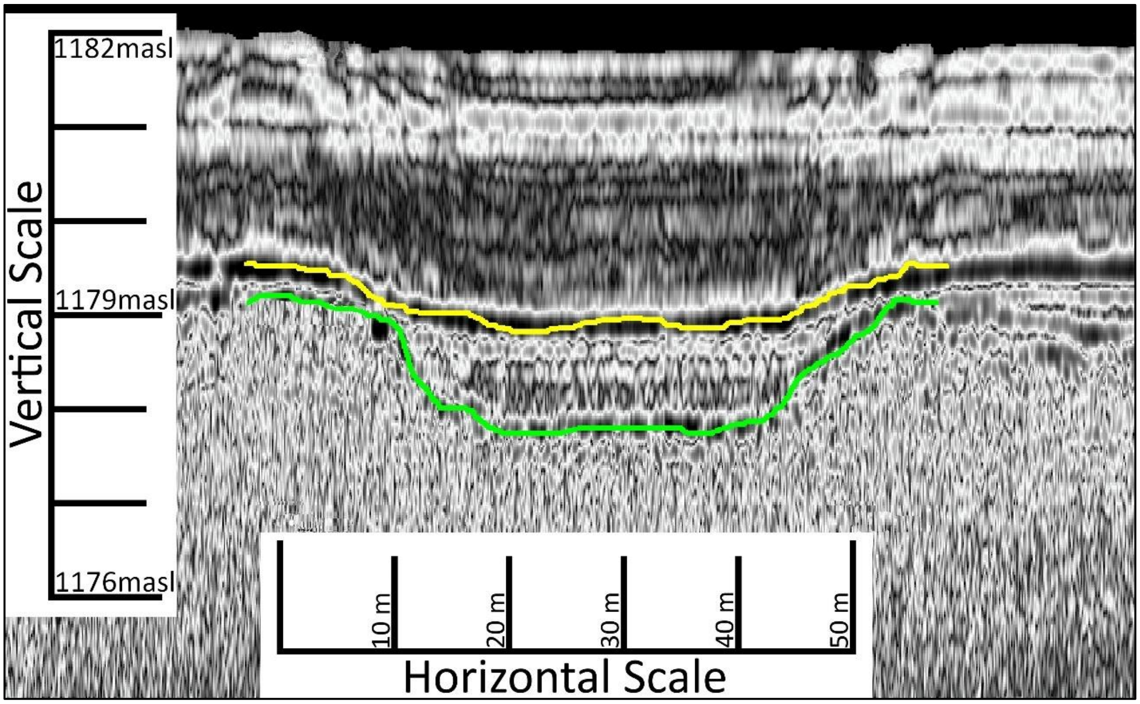

Figure 3.10. Feature 3 from sub-bottom profile Transect 7. The yellow line is the channel along Reflection 1 and the green line is the channel along Reflection 2.

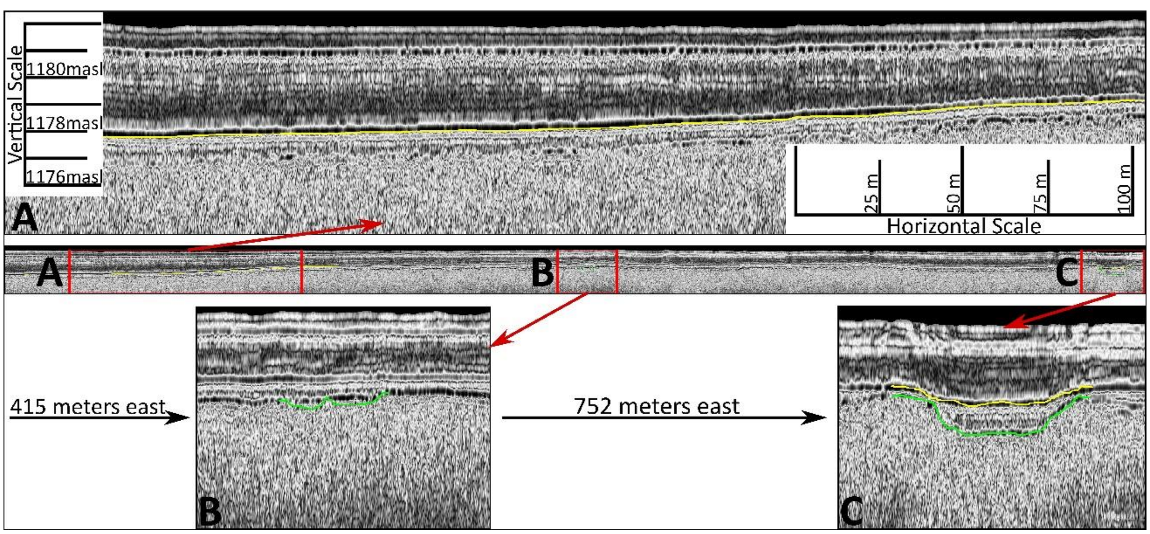

Figure 3.11. Image showing the relative positions of A) Feature 1, B) Feature 2, and C) Feature 3 along transect 7. The full transect 7 profile is depicted in the middle of the image.

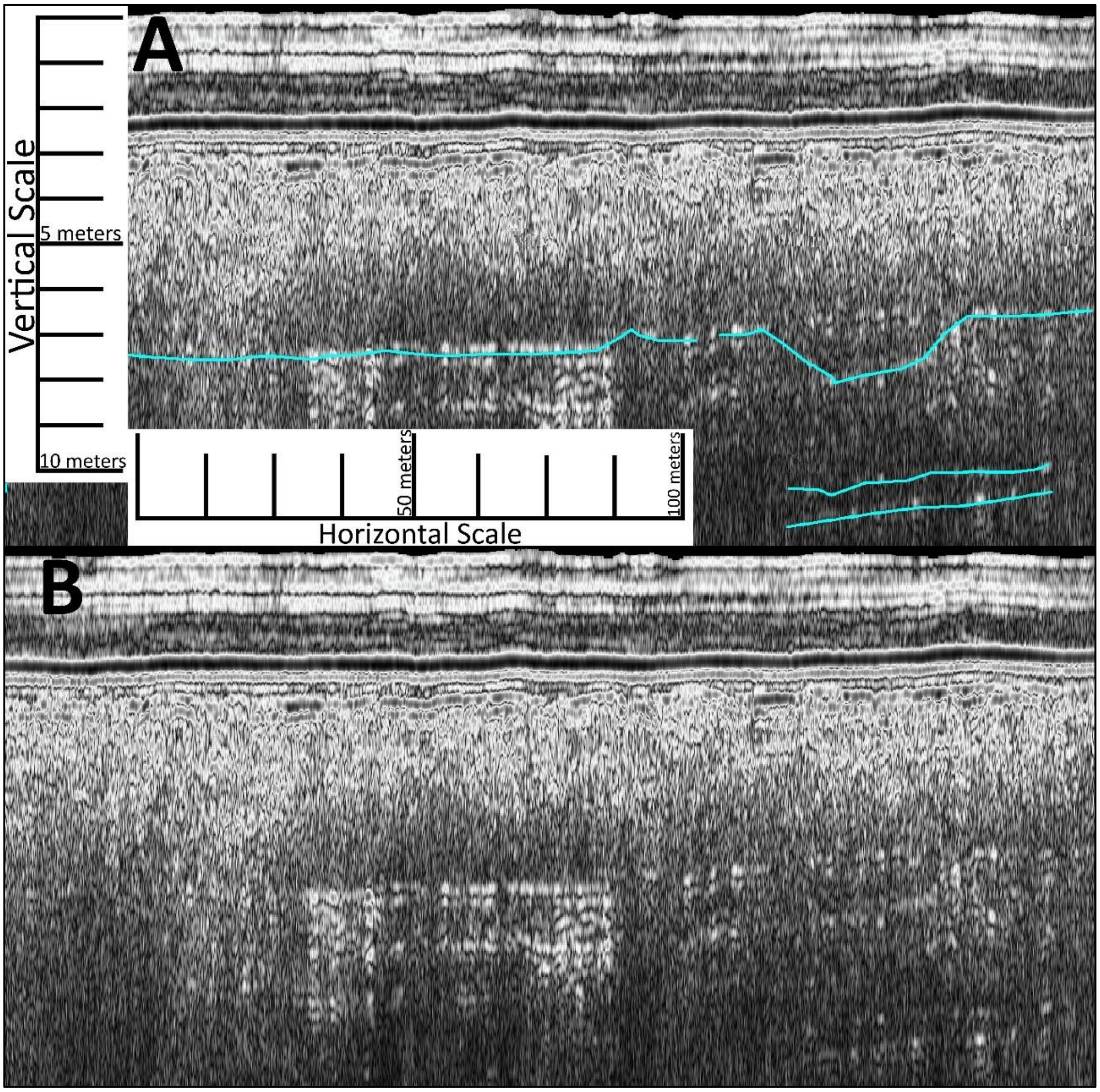

Figure 3.12. Eastern edge of Transect 7 showing deep sub-bottom profile stratum below Reflections 1 and 2. A) Blue lines denoting a possible deep channel and diving strata. B) Deep reflections without any notations.

buried features such as possible channels **(**Figure 3.12). Their ephemeral and uncertain nature, however, preclude them from being labeled as features.

In addition to the above sub-bottom features and observations, certain transect profiles show unique strata that may indicate other preserved, buried features within Walker Lake. Transects 6 and 8 both show dipping in Reflection 2 ~775 m from their eastern edge. Transects 4 and 5 show a dip in Reflection 2 500-600 m east of their western edge, and transect 3 shows a similar feature 400-450 m east of its western edge.

Reflection 1 remains relatively linear across all the above features except for the gradual rise associated with Feature 1. Dips sometimes occur in Reflection 1 where features observed in Reflection 2 are pronounced, but undulations in Reflection 1 arealways less pronounced than the dips in Reflection 2 (e.g. Feature 3). This further suggests Reflection 1 dips represent infill of the features associated with Reflection 2. The linear reflections 7-12 m below Reflection 2 are relatively uncommon, and where they appear, they are not as clear as the upper-profile reflections (Figure 3.12). Nonetheless, these deep reflections do not appear to mirror the upper profiles, suggesting they are not reflection multiples but instead unique strata preserved below Reflection 2.

As discussed above, examination of these sub-bottom profiles was used to determine the best locations to investigate intact, lowstand geomorphic features within Walker Lake. The two most distinct features were selected for testing: Feature 1 and Feature 3. I selected Feature 1 because it was a common across all the transects. The ideal location for testing the feature was determined to be where it stopped rising along transect 7, east of the most pronounced slope shown in Figure 3.8. Testing this location allowed me to investigate the highest point along the rise of Reflection 1. TB-1 was placed here to test whether Feature 1 represents sands of a shoreline and a recent transgression event. Feature 3 was selected because it is the strongest evidence for a fluvial channel in the sub-bottom data. I selected the western and eastern edges of this feature between transects 5 and 7 to determine if overbank deposits or other transgressional sediments were present. TB-2 and TB-3 were placed at these locations, respectively (Figure 3.3).

3.3.1.1. Summarizing the Sub-bottom stratigraphy

The sub-bottom profile stratigraphy, shown in Figure 3.7, has numerous reflections that may represent distinct depositional environments. As noted, most of the sediments above Reflection 1 are likely parallel lake deposits, so they should be fine-grained lacustrine sediments. Reflection 1 and Reflection 2, however, appear to represent different sediment densities, textures, and shapes indicative of either higher-energy lacustrine sediments or non-lacustrine, fluvial depositional environments. Between these are reflections similar to the upper parallel lake beds, and the general nature of the reflection below Reflection 2 is a homogeneous signal that may consist of additional deep-water deposits. Within this lower signal are some linear reflections, but these must be further investigated to verify their nature. Combined, the sub-bottom profile appears to have five distinct sediment packages, which based on the model presented above, consists of a sequence of fine-coarse-fine-coarse-fine sediments, with the coarse sediments represented by Reflections 1 and 2. The preservation of features identified through sub-bottom profiling provides a starting point for additional investigations to clarify the history of the lake. The subsurface testing, tephra analysis, and radiocarbon dating described below help to clarify the nature of these sediments and features.

3.3.2. Excavation Block Descriptions

Here I present results from test blocks excavated in 2015 and 2017. These blocks were placed to better understand the stratigraphic context of the sediments within Walker Lake. My excavations produced important paleoecological data, including fish and macrobotanical remains. They also provide important details about the depositional history of associated landforms key in reconstructing the lake's late Holocene history.

3.3.2.1. 2015 Test Block

Test block "2015Test" was located approximately 3.5 km south of the 2019 shoreline (Figure 3.4). In total, 50 cm of sediment was excavated, and 147 cm of sediment was captured in the core. The core and excavation data were useful for establishing upper lake-sediment depths. This block provided a foundation for stratigraphic observations and methods applied to later underwater work.

The sediment collected in the 2015Test core included five distinct strata (Figure 3.13). These had abrupt-to-clear, straight contacts, save the strata I-II contact, which was wavy. The lowest two strata (I and II) consisted of 50.8 cm of silty clay. Stratum I was dark gray, and stratum II was black. Stratum III was a gray, sandy clay loam containing fine-to-very-fine, volcanic-ash material. This tephra deposit was 2.2-cm thick and is the same tephra deposit associated with cutbanks 2, 3, 5, the upper tephra in cutbank 7, the

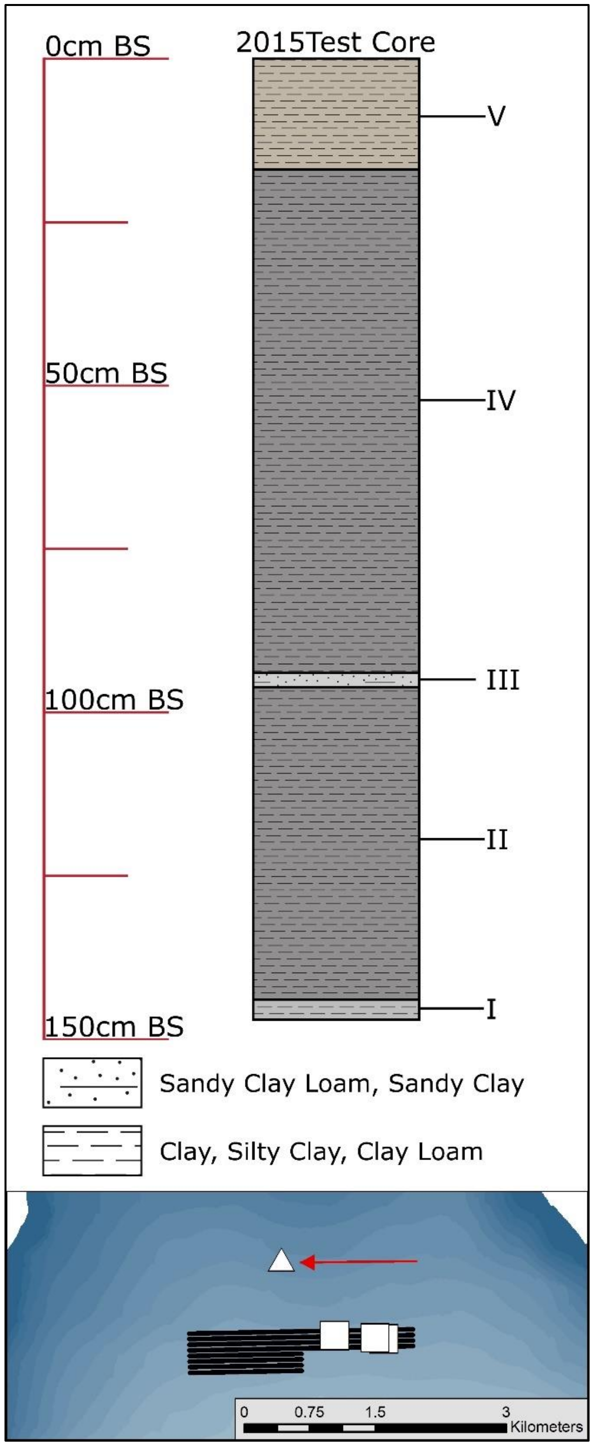

Figure 3.13. Profile of the core recovered from 2015Test excavation block. Inset map with arrow shows the position of the excavation location and associated core relative to the lake bathymetry, sub-bottom transects, and all other excavation blocks.

auger, and the 2017 test-block excavations (see tephra analysis results below). Strata IV and V consisted of 94 cm of silty clay loam. Stratum IV was black and organic rich, while stratum V was brownish gray and contained fewer organics.

Excavation of 0.5 m of sediment in 2015Test was quickly completed. Once the plant growth and upper, less-compact sediments were cleaned from the excavation area, the field crew excavated the five 10-cm levels in two days. All the sediment excavated was silty clay grading to silty clay loam based on in-water observations. Because materials were only identified in the field and palaeobotanical counts were not recorded from this initial test block, specific numbers are not presented; however, fish bones, fish scales, and vegetal material were observed in the screen.

3.3.2.2. Test Block TB-1

The first of the 2017 blocks discussed here was excavated at the high point of Reflection 1 along Transect 7, east of the most pronounced sloping observed in Feature 1. Its surface elevation was ~1,181.9 masl. We collected two cores from TB-1. The northeast core extended to 2.82 m BS and the southwest core extended to 2.80 m BS. These contained a representative profile of the TB-1 stratigraphy, consisting of nine identified strata with mostly abrupt, smooth contacts (Figure 3.14). The only exceptions were contacts between strata I and II (clear and irregular), strata II and III (abrupt and irregular), and VIII and IX (abrupt and wavy).

The lowest stratum, stratum I, consisted of 10 cm of distinct sand-to-sandy loams separated into three sub-strata (Ia, Ib, and Ic) that were dark grayish brown in color

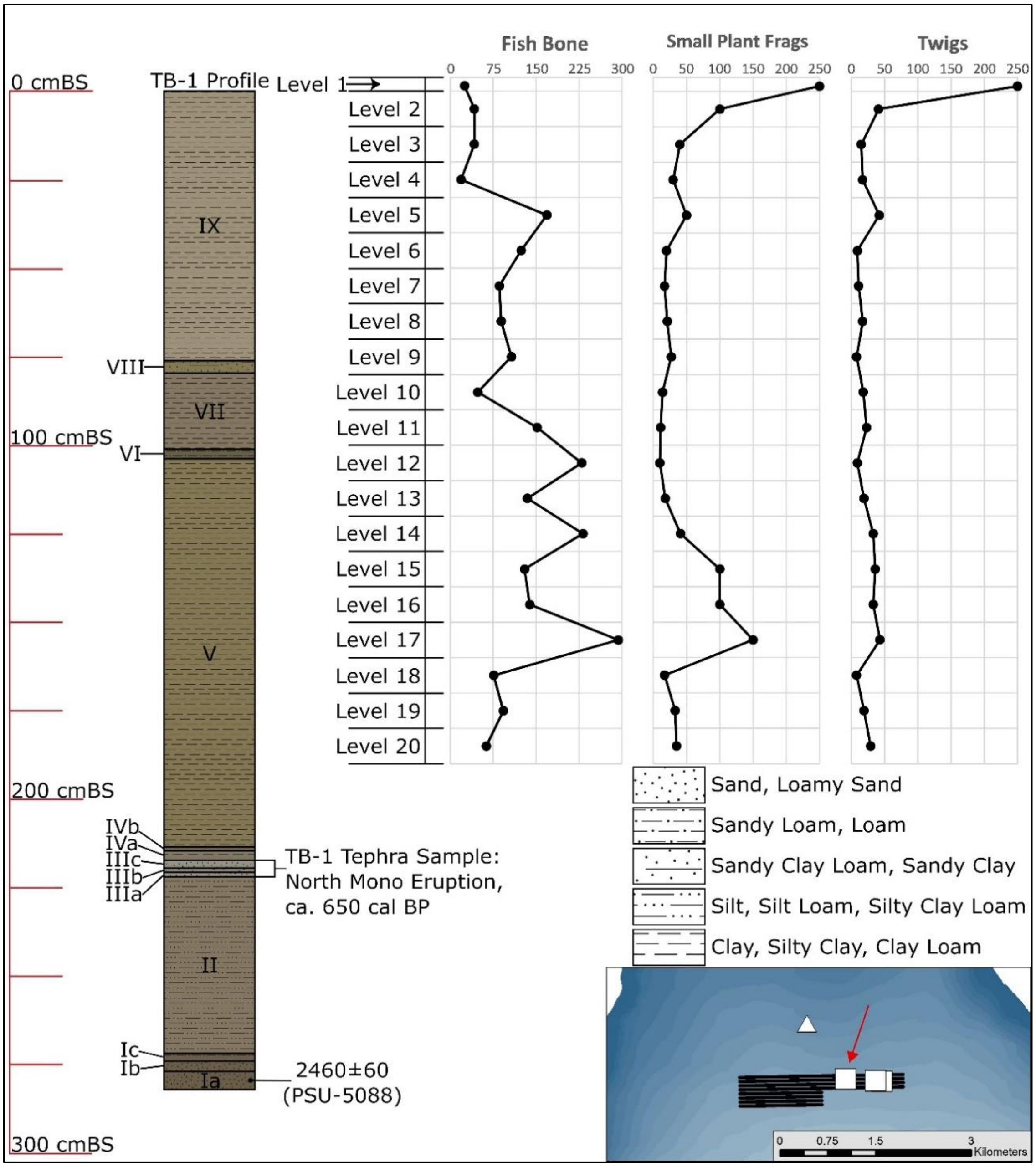

Figure 3.14. Representative stratigraphic profile and distribution of select floral and faunal materials recovered from TB-1. Excavated sediments extend to 1.89 m BS and core sediments extend to 2.80 m BS. Colors in the profile are the Munsell colors identified for each sediment. Inset map with arrow shows the position of the excavation location and associated core relative to the lake bathymetry, sub-bottom transects, and all other excavation blocks.

(2.5Y4/2 and 10YR4/2). Stratum II was a 50-cm-thick deposit of grayish-brown (2.5Y5/2) silty clay loam. Stratum III was a 4.6-cm-thick tephra deposit broken into three, fining upwards sub-strata: IIIa was a gray (5Y 6/1) medium sand, IIIb was a light-gray (10YR 7/1) fine sand, and IIIc was a gray (5Y 6/1) very fine sand (see tephra analysis results below). Above stratum III, stratum IV was broken into two subunits (IVa and IVb) and consisted of 3.6 cm of olive-gray (5Y 5/2) and grayish-brown (2.5Y 5/2) clay loam to fine sandy loam. Stratum V was a 110.1-cm-thick deposit of olive (5Y5/3) silty clay. Stratum VI was a 2.7-cm-thick deposit of olive-gray (5Y4/2) loam containing fine sands. Above it, strata VII-IX included 101 cm of grayish-brown-(2.5Y 5/2)-to-light-brownish-gray-(2.5Y 6/2) clay containing a 3.5-cm-thick olive (5Y5/3) sandy clay loam with fine sands (stratum VIII). Stratum IX was the top deposit in the cores.

When I compared the core stratigraphy detailed in the lab to the stratigraphic descriptions of the block recorded in the excavation field logs, it was clear that excavation in block TB-1 did not extend deeper than stratum V (Figure 3.14). The overall excavation depth of TB-1 was 2 m BF or 189 cm BS, and stratum V extends to 213.8 cm BS. Additionally, the lowest level excavated, 179-189 cm BS, had the same texture as stratum V, a silty clay. Generally, the in-field descriptions of level sediments accurately reflect the sediment observations from the cores. One major difference was that we did not observe stratum VIII during excavation; I relied on the cores to provide this detail.

Of all the materials collected from screening during TB-1 excavation (Figure 3.14), only level 14 contained faunal material observed during excavation: a concentrated deposit of preserved fish bone that was collected from the screen. Level 1 was filled with plant material including wood, bark, twigs, and other recently deposited flora. The amount of woody material from this level was too great to provide an exact count ($n > 225$). Fish remains were relatively low in number ($n = 25$) for the top level. Below it, the amount of flora steadily declined while the fish remains generally increased to level 5 where there was a spike ($n = 169$) in fish bone. This spike was combined with an increase in plant remains. Plant remains decreased in the next level and remained relatively low ($n < 100$) until level 15. Fish remains and relative charcoal counts stayed high ($n \geq 90$ and $n \geq 3$) until level 10 where there was a drop in total faunal and floral material recovered from the screen ($n = 112$). Fish remains spiked ($n = 152$) with the next level and remained high with a slight decrease ($n \leq 95$) in levels 18-20. From level 15-17, plant remains were exceptionally high ($n \geq 145$) before dropping precipitously ($n \leq 80$) in levels 18-20. Very small amounts of plant seeds/shells, gastropod shells, and tufa were found throughout the levels with no clear patterning.

3.3.2.3. Test Block TB-2

TB-2, placed on the western terrace of Feature 3 at an elevation of ~1,182.3 masl, contained three cores capturing a total of 250.8 cm of sediment from the excavation block across nine strata (Figure 3.15). These had abrupt, smooth contacts with one exception; the strata I-II contact was clear and smooth. Strata elevations differed across the cores, appearing to dip to the south. This pattern was also noted during block excavation. The difference in elevation was particularly noticeable below 144 cm BS

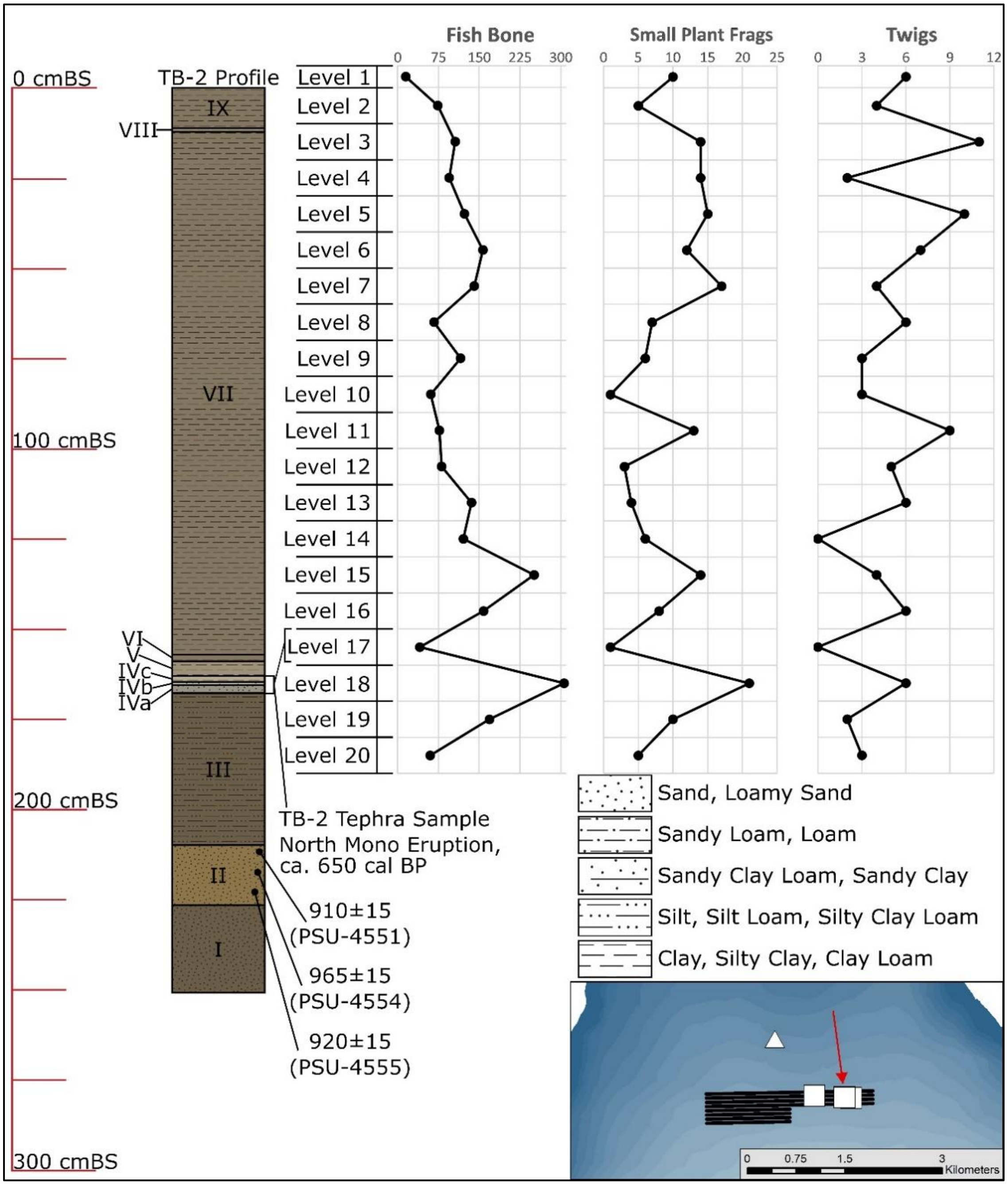

Figure 3.15. Representative stratigraphic profile and distribution of select floral and faunal materials recovered from TB-2. Sediments were excavated to a depth of 1.90 m BS and core sediments were captured to a depth of 2.58 m BS. Colors in the profile are the Munsell colors identified for each sediment. Inset map with arrow shows the position of the excavation location and associated core relative to the lake bathymetry, sub-bottom transects, and all other excavation blocks.

where the northeast core had a much thinner presence of stratum III than the center and south cores.

The deepest stratum in TB-2 (stratum I) was only identified in the south core. It was a 24.3-cm-thick deposit of dark-grayish-brown (2.5Y 4/2), poorly sorted, angular-to-sub-angular, fine-to-medium sand. It contained abundant woody organics and few small gravels. Stratum II was a light-olive-brown (2.5Y 5/4), well-sorted, loamy medium sand containing abundant woody organics and ranging in thickness from 7.6-16.5 cm. The stratum dipped sharply to the south with upper elevations of 144.0 cm, 208.3 cm, and 210.0 cm BS in the northeast, center, and south cores, respectively. Stratum III ranged from 2.0-42.3 cm in thickness and was a dark-grayish-brown (2.5Y 4/2) silty clay grading to a silty clay loam. The different thicknesses of the stratum in the northeast (2 cm), center (18.3 cm), and south (42.3 cm) cores accounted for much of the dipping observed in TB-2. Stratum IV was a tephra deposit ranging from 3.9-4.3 cm in thickness. Like the TB-1 tephra, IV was separated into three, fining upward substrata: IVa was a gray (5Y 6/1) very-fine-to-fine loamy sand; IVb was a light-gray (2.5Y 7/2) sandy clay loam containing very-fine-to-fine sands; and IVc was a light-gray (2.5Y 7/2) clay loam. Above the tephra, all the sediment deposits were fine grained. Strata V and VI included 2.3-5.8 cm of clay loam with few medium-sized sand grains and grading from light brownish gray (2.5Y 6/2) to grayish brown (2.5Y 5/2) in color. Stratum VII was a 68.0-123.7-cm-thick, grayish-brown (2.5Y 5/2) silty clay. The different stratum-VII thicknesses between the northeast and south cores account for the remaining difference in strata elevations across the block. The rest of the profile consisted of stratum VIII, a clay loam with medium-fine sand grains that was 1.1 cm thick and light brownish gray (2.5Y6/2) in color, and stratum IX, an 11-cm-thick clay, grayish brown (2.5Y5/2) in color.

TB-2 was excavated to an overall depth of 2 m BF or 190 cm BS. In-field sediment observations made during underwater excavation closely match the core stratigraphy recorded in the lab. Level 1 was capped with a slightly denser, 1-2-cm-thick deposit that was not observed in the northeast core. During excavation, I described nearly all the inundated TB-2 sediments as black, dark-gray, or dark-brown silty clay. The correlated core sediments, exclusive of the tephra, included clay, clay loam, silty clay loam, and silty clay. The discrepancy between underwater field observations and the cores was an under estimation of sands in the field. Level 17a, from 160-167 cm BF (150-157 cm BS) was described as a light gray sandy clay loam. This layer was the tephra deposit in the cores and found within the range of depths recorded in the northeast and south cores. The difference between tephra elevations recorded in the excavation and the cores was likely due to ~8-10 cm of sediment compaction within the core.

Compared to TB-1, the amount of flora recovered in the screens from TB-2 was minimal. In general, the amount of fish remains was comparable with those found in TB-1. The highest amount of flora in TB-2 was from levels 3-7 ($n \geq 19$). Below this, the flora dropped off and was dominated by small pieces ($n \leq 15$). Levels 11, 15, and 18 both contained floral counts similar to levels 3-7, but they were surrounded by levels with a dearth of plant material. The highest amounts of fish bones were in levels 6-7, 15-16, and 18-19 ($n > 140$). Charcoal, tufa, gastropod shells, and plant seeds/shells were also present throughout the block, but in very low numbers. A single feather was found in level 5.

3.3.2.4. Test Block TB-3

Block TB-3 was located on the eastern terrace of Feature 3 at an elevation of ~1,182 masl. The cores captured a long sedimentary record extending 285 cm below the top of the excavation block (Figure 3.16). Similar to the pattern observed in the cores from TB-2, differences in sediment elevations between the northeast and southwest cores indicated dipping to the south. Contacts between the strata were clear and irregular between strata I-IV and abrupt and smooth between IV-IX with one exception: the strata V-VI contact was abrupt and wavy.

The lowest deposit from TB-3 was a clay located below the lowest sands. As this was the only clay observed below the lower sands across all of the 2017 excavation blocks, I decided to label it stratum 0. Stratum 0 was only in the southwest core and described as a 2.8-cm-thick, dark-gray (7.5YR4/0) clay. Above it, stratum I was the lowest stratum in the center and northeast cores. It consisted of a 7.0-9.3-cm-thick, grayish-brown (2.5Y 5/2) deposit of poorly-sorted, coarse-to-fine sandy loam interdigitated with sandy clay loam. Next, stratum II was a 1.5-3.9-cm-thick gray (7.5YR5/0) clay. Stratum III was separated into three sub-strata (IIIa, IIIb, and IIIc) representing a fining upward sequence of sand and fine-grained sediments. Strata IIIa consisted of a poorly-sorted, angular-subangular, fine-to-coarse sand, ranging from 10.3-18.0 cm in thickness and dark grayish brown (2.5Y 4/2) in color. Stratum IIIb was a

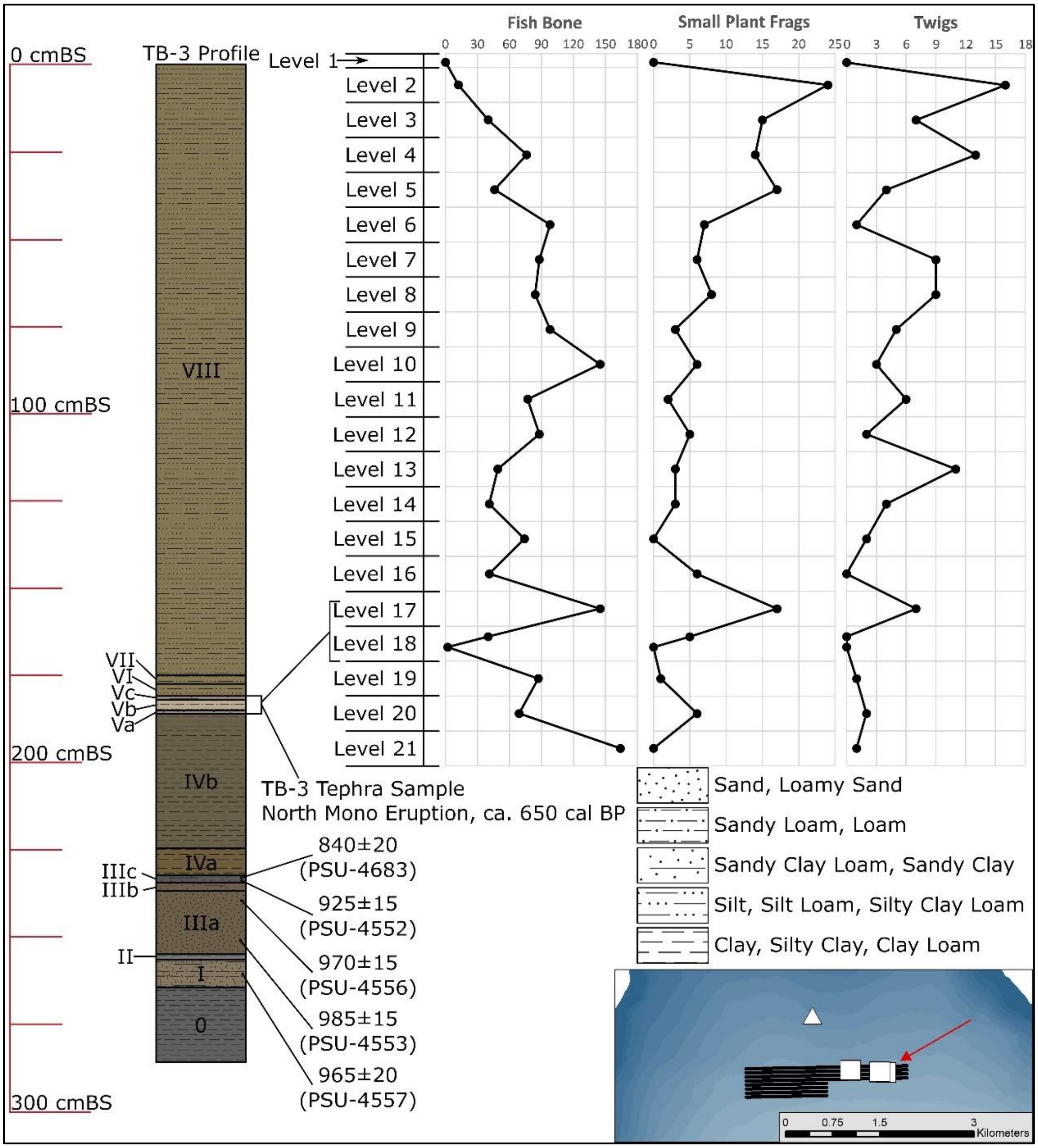

Figure 3.16. Representative stratigraphic profile and distribution of select floral and faunal materials recovered from TB-3. Excavation depth extended to 2.01 m BS and core sediments were captured to a depth of 2.85 m BS. Colors in the profile are the Munsell colors identified for each sediment. Inset map with arrow shows the position of the excavation location and associated core relative to the lake bathymetry, sub-bottom transects, and all other excavation blocks.

sandy clay loam with poorly-sorted, medium sands, ranging from 1.0-3.8 cm in thickness and dark grayish brown (10YR 4/2) in color. Stratum IIIc is 1.6-3.3 cm of black (2.5Y 2/0) sandy clay containing poorly-sorted, coarse-to-fine sand. Stratum IV was a 40.0-49.1-cm-thick package of sediment ranging from silty clay to silty clay loam in texture and dark grayish brown (2.5Y 4/3) to olive gray (5Y 4/2) in color. It was further separated into two sub-strata (IVa and IVb) based on these distinctions. Stratum V was a single tephra deposit that measured 4.4-4.6 cm in thickness and was separated into three sub-strata (Va, Vb, and Vc). Va was a loamy fine sand light brownish gray (10YR 6/2) in color. Vb was a sandy loam and light gray (2.5Y 7/2) in color. Vc was a sandy clay loam light brownish gray (2.5Y 6/2) in color. Above the tephra, strata VI to VIII make up a 90.5-143.4-cm-thick package of olive (5Y-5/3) silty clay loam (strata VI and VIII), separated by a 1.4-2.5-cm-thick deposit ranging from fine sandy loam to silt loam with few medium-fine sands (stratum VII).

TB-3 was excavated to a depth of 210 cm BF (201 cm BS). This block, like TB-2, was capped by a 1-2-cm-thick, dense sediment package that did not appear in the core. The sediment observations made during excavation generally align with the core observations; however, the sand content was again underestimated in the field. Most field sediment classifications were silty clay, but the correlated core sediments were primarily silty clay loam. Stratum VII was not identified during excavations. Stratum V, the tephra, was noted from the lower portion of level 17 in the northern half of the block through level 18 in the southern half. It was described as a ~4-cm-thick, light-gray sandy clay and clay loam dipping sharply to the south. Level elevations most closely aligned with the below-surface elevations from the southwest core, exemplified by the fact that elevation of levels 17-18 were within ~10 cm of corresponding stratum V in the southwest core. This suggests that the sediments in the northeast core were compacted as a result of the coring process, resulting in at least 20 cm higher BS depths than those in the undisturbed stratigraphic profile.

The materials collected from the screens during TB-3 excavation are shown in Figure 3.16. Like with TB-2, the amount of flora was significantly less than that observed in TB-1. This block also had the lowest overall occurrence of fish remains, charcoal, and gastropod shells. Generally, floral presence significantly dropped in number below level 5 (n < 20), with increased twig counts in level 13 (n = 11), and an overall flora increase in level 17 (n = 29). Fish bone counts steadily increased to level 10 where they sharply declined beginning with level 11 and then continued to decline (n < 88). Level 17 showed a spike in fish bones (n = 145), similar to the flora counts. After level 18b, fauna once again increased with another sharp spike in level 21 (n = 164).

3.3.2.5. Summary of Test Excavation Stratigraphy

Each of the test blocks consists of a similar stratigraphic sequence. The upper ~2-2.5 m of sediment consists of fine-grained clays and silty clays. These are largely homogeneous, with one or two thin lenses with higher sand content (e.g., TB-1 stratum VI and TB-2 stratum VIII). These lenses are minimally distinguishable from the surrounding sediments and may reflect short-term lake-level recessions in which the local environment remained inundated, but the depth decreased to the point that higher energy sediment transport could occur in a littoral, shoreline, or nearshore environment. Overall, these thick deposits of fine-grained material make up all the material shown above Reflection 1 in the sub-bottom profiles. In each test block, save 2015Test, the fine-grained material abruptly changes to coarser sands and sandy loams (2015Test did not record any coarse-grained sediments). Based on their depth, these coarse-grained materials represent the same as those marking Reflection 1 in the sub-bottom profiles, and they illustrate a relatively straight-forward sequence across more than 2.5 m of sediments.

Across the test blocks, there are two to five distinct sediment packages with markedly different grain size. In TB-1 and TB-2 these deposits generally create a coarse-to-fine sediment sequence; however, there is some variability. These sequences record a single major recession event that reached out to or beyond the test block elevations, represented by stratum I in TB-1 and corresponding strata I-II in TB-2. In TB-1, stratum II marks a transition to deep-lake sediments. The TB-2 profile expresses a switch to deposition of fine-grained sediments and deep-lake conditions, beginning with stratum III. The TB-3 sequence is yet more complex with a set of changes from fine to interdigitated fine and coarse materials in stratum I. This switches to a thin, fine deposit, and then to a coarse package in stratum IIIa, which fines upward to IIIc and the large fine package beginning with stratum IV. TB-3 may point to two recession events, one represented by stratum I and another by stratum III. The sequence from clay to interdigitated sandy loam/sandy clay loam and then back to clay in strata 0-II appears to mark a period in which lake level dropped from relatively deep levels to shallower depths (between 1180-1185 masl) and then returned to deeper waters above 1,185 masl. This was then followed by stratum III sands, representing a more extensive recession of the lake at this location and development of a shoreline feature. Strata IV-VIII represent a final switch back to much finer sediment deposition and lake transgression. It is interesting to note, however, that stratum VII expresses a sandy interruption in the deposition of silty clay loam and may signal a nuanced pattern from deeper lake to shallower lake and back to deeper lake during this final stage.

Each test block contained a clear tephra deposit within these sediment sequences. It was in stratum III in both 2015Test and TB-1, in stratum VI in TB-2, and in stratum V in TB-3. The tephra packages were fining upward, with the lowest portions consisting of coarse, sand-sized ash, which then graded to finer sediments representing lighter ash slowly settling to the lake bottom. Fine-grained sediments were located above and below the tephra packages. Based on the stratigraphy, it is clear tephra deposition occurred when the test block locations were inundated, and there is no evidence that lake level fell below any of the test block elevations after the tephra was deposited. The location of the tephra in the test blocks suggests it should be found above Reflection 1 in the sub-bottom profiles, but I was not able to delineate a specific reflection showing the tephra marker horizon.

3.3.3. Walker River Cutbank and Auger Test Records

The cutbanks and auger test described here represent the intact stratigraphic record within the Walker River Valley. Adams' (2007) extensive discussion of eight

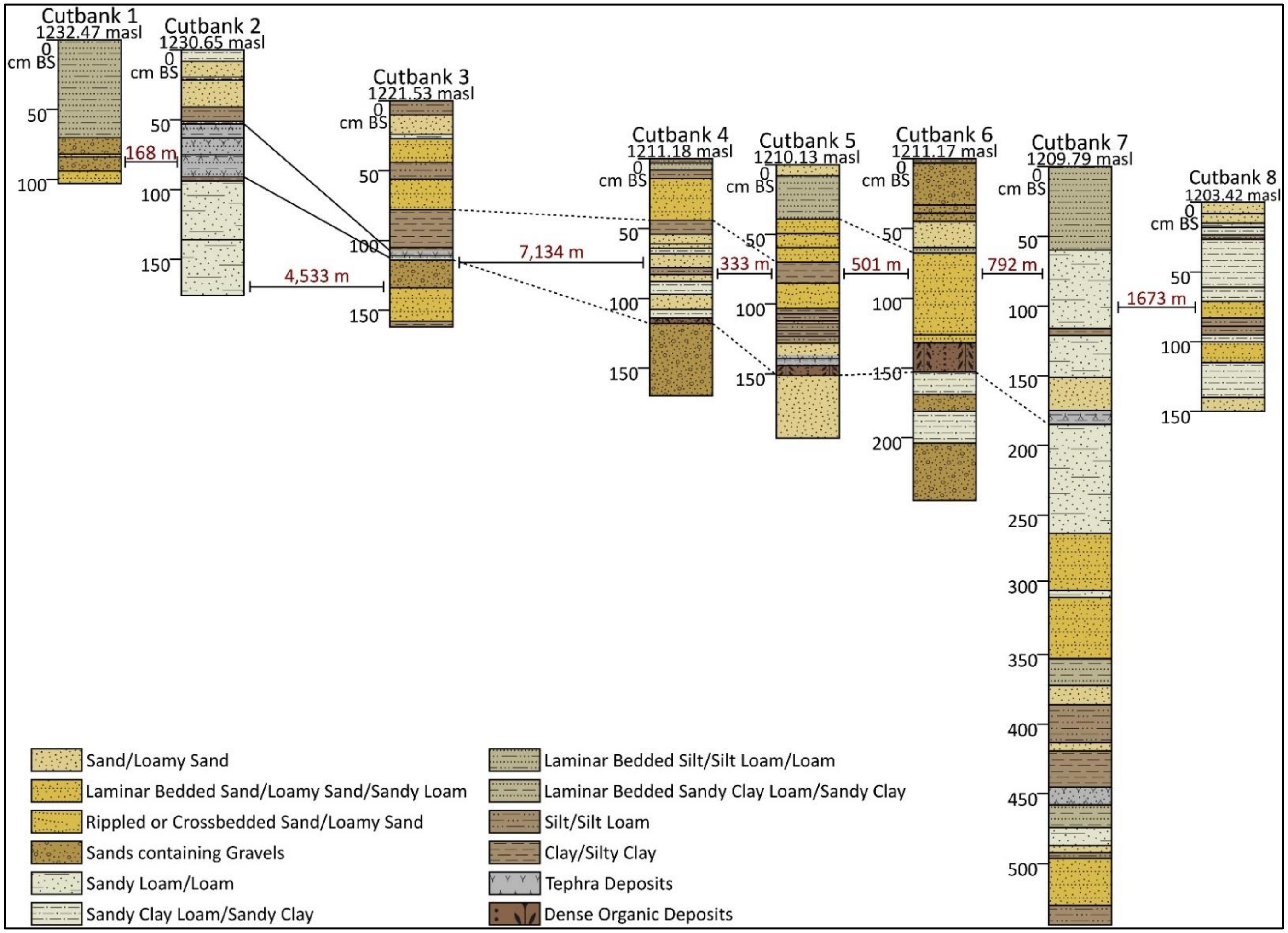

Figure 3.17 Sediment profiles from cutbanks 1-8. The relative masl elevations of the top of each cutbank are to scale. The horizontal distances between the profiles are identified and representative across the image.

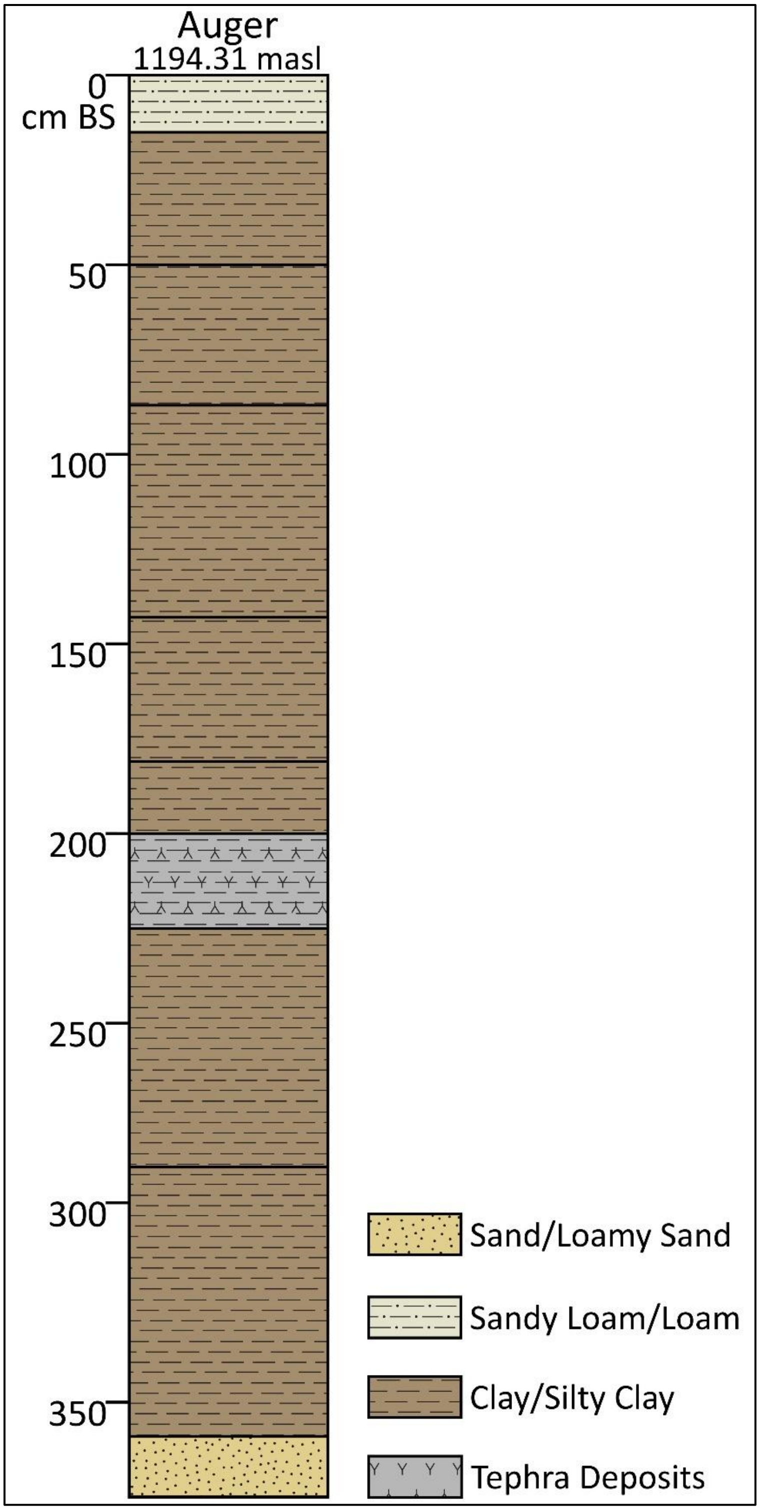

Figure 3.18. Representative stratigraphy of the augered sediment recorded at the north end of Walker Lake.

stratigraphic profiles reveals important, chronologically associated evidence for lake transgression and recession. The following profiles reflect this information and identify additional locations where lake-history evidence is preserved and may be studied. Figure 3.5 shows the study locations and Figures 3.17 (cutbanks 1-8) and 3.18 (the Auger) provide visual representations of the profiles.

3.3.3.1. Cutbank 1

This cutbank deposit at an elevation of 1,232.47 masl includes 103 cm of visible stratigraphy separated into at least three depositional packages of sand and silt. The lowermost stratum consists of a 9-cm package of compact, bedded medium sands. Above this is 24 cm of loose, massive, sub-angular gravelly coarse sand to sandy gravel. A thin, 2-cm-thick band of granular fine sand separates the lower gravelly sand and the higher sandy gravel. The upper 70 cm is a compact, laminar, bedded silt loam.

3.3.3.2. Cutbank 2

This exposure, at an elevation of 1,230.65 masl, includes 176 cm of visible stratigraphy consisting of at least six packages with varying amounts of sand, silt, and clay. The lowest package consists of 101 cm of silty clay loam to clay, with the bottom 40 cm being massive and gleyed. The next 45 cm has prismatic structure and redoximorphic (redox) concentrations followed by 16 cm of compact, thin bedding containing white tephra deposits. Above these fine-grained sediments is a 12-cm-thick deposit of moderately compact, laminar, fine sand containing white tephra material. This is capped by 10 cm of compact, massive, clay loam containing redox concentrations and white tephra concentrations. Above the clay loam is a 12-cm-thick deposit of compact sandy to silty loam. Next is 33 cm of loose, massive, medium to coarse sand containing a 1-cm-thick, compact, sandy-loam lens. Finally, the top stratum is an 8-cm-thick deposit of fine sandy loam with a weak A horizon.

3.3.3.3. Cutbank 3

This stratigraphic column is at 1,221.53 masl and includes more than 162 cm of visible stratigraphy separated into at least nine sediment packages. The bottom unit consists of 4 cm of compact, prismatic clay loam. Overlying this is a 47-cm sandy package, the bottom 24 cm of which is compact, laminar, medium-to-fine sandy loam. The upper 23 cm contains a fining-upward deposit of compact coarse sandy gravels grading to loamy fine sands. The top 3 cm of this package contains white tephra deposits similar to those observed in cutbank 2. The sands are capped by a 31-cm-thick deposit of clay loam with prismatic structure, the bottom 6 cm of which also contain tephra material. Next is a 12-cm-thick, laminar, moderately-compact fine sand. Above this is 12 cm of compact silt loam followed by 17 cm of massive fine silty sand containing lenses of poorly-sorted, coarse sand with gravels. Next is a 3-cm-thick, blocky silty clay capped by a 14-cm-thick massive, loose, and poorly-sorted, medium-to-coarse sand. The top 10 cm is silt containing a weakly developed A horizon.

3.3.3.4. Cutbank 4

Cutbank 4 has 170 cm of visible stratigraphy at an elevation of 1,211.18 masl, including abundant sand deposits and preserved charcoal. The profile can be divided into at least six packages of sand, silt, and clay sediments. The lowermost package is 86 cm in thickness, consisting of 56 cm of compact, poorly-sorted, fine sandy loam with gravels. The top 4 cm of this deposit contains charcoal and organic material. This is overlain by 30 cm of alternating compact-to-loose-to-compact fine sands. Next is a 5-cm-thick compact silt deposit. Overlying the silt is another package of sands, measuring 24 cm in thickness and alternating between loose and compact fine sands with the upper 5 cm consisting of a compact medium sand. Next is a 10-cm-thick blocky clay loam, followed by a 30-cm-thick package of compact, laminar, loamy fine sand. Finally, the profile is capped by 14 cm of loose-to-laminar silt loam with a weakly developed A horizon.

3.3.3.5. Cutbank 5

This cutbank, with an elevation of 1,210.13 masl, has 196 cm of visible sediment and contains an organic-stained deposit with large charcoal fragments. The profile includes at least eight packages with varying amounts of sand, silt, and clay. The lowest package is 52 cm of massive, loose medium sand, the upper 7 cm of which is charcoal-stained and contains charcoal fragments up to 1 cm in size. Next is a 5-cm-thick deposit of blocky clay with red iron staining and white tephra concentrations. Capping the clay is 11 cm of slightly compact, massive, medium sand containing white tephra concentrations near the lower clay. A 25-cm-thick compact silt loam-to-clay package is above the sand. Within this package, the silt-rich deposits are laminar, while the clay-rich deposits are blocky. It also contains a thin lens of cross-bedded, fine sand. Above the silt-to-clay package is an 18-cm-thick deposit of compact, cross-bedded fine sands containing ripple structures. Next is 15 cm of compact blocky clay loam capped by a 62-cm package of compact laminar silt, loamy fine sand, and fine sand. Ripple structures are found near the bottom of this package. The top sediment is 8 cm of loose, angular, medium sand containing abundant roots and organics.

3.3.3.6. Cutbank 6

Cutbank 6 has 245 cm of visible stratigraphy at an elevation of 1,211.17 masl, including a dark, organic-rich deposit. At least eight packages with varying amounts of sand, silt, and clay make up this profile. The lowest is a 41-cm-thick, massive, poorly-sorted, angular, coarse-to-medium sand with gravels. Next is 23 cm of massive, compact, fine sandy loam capped by 12 cm of bedded, moderately-compact, poorly-sorted, coarse-to-fine sand with gravels. Above the sand is 37 cm of compact, massive sandy loam grading to loamy sand. It preserves abundant organic material, including charcoal, fish bone, and juniper bark. Above the organics is 6 cm of slightly-compact clay loam capped by 81 cm of compact fine sand grading to loamy fine sand. The lower portion of this package is laminar, while its upper 19 cm is massive. Next is a 42-cm package of massive, poorly-sorted sands containing gravels. The top 3 cm of the profile is a massive silt.

3.3.3.7. Cutbank 7

This cutbank has an extensive profile located at 1,209.79 masl, including 544 cm of visible stratigraphy with 10 packages of sand, silt, and clay. The large profile is a result of its location just below a narrow point in the WLB allowing for increased fluvial energy and deeper cutting. The lowest package is a 14-cm-thick deposit of compact, massive silt loam capped by 34 cm of moderately-compact, laminar medium sand. Next is a 51-cm-thick set of thin, compact fines, ranging from silt to loamy fine sand, and then loam to clay loam. The top 13 cm of this package contains white tephra material. This is capped by 26 cm of blocky subangular clay. Above the clay is a 66-cm-thick package of alternating loose sand and compact silt. The upper 19 cm of silt contains three ~1-cm-thick clay beds. This is in turn capped by 90 cm of compact, laminar, fine sand grading to a loamy fine sand. This package contains a 1-cm-thick clay lens and a 5-cm-thick lens of compact, silty clay loam. Above this is 88 cm of compact, columnar-to-blocky silty clay loam grading to clay. The top 10 cm of this package contains white tephra deposits. Overlying the clay is 24 cm of loose, massive, medium sand. This is capped by 91 cm of compact, massive, sandy loam containing five thin clay lenses. Most of these are ~1-cm thick, though a 5-cm-thick clay deposit was also noted. The top of the profile consists of a 60-cm-thick, compact, loam deposit containing thin, fine-sand laminae throughout.

3.3.3.8. Cutbank 8

Cutbank 8 is closest to Walker Lake. At an elevation of 1,203.42 masl, it has 150 cm of exposed stratigraphy containing five packages of sand, silt, and clay. The bottom of the profile is a 50-cm package of sand and fine sandy loam. The upper 40 cm of these sediments are laminar and dip to the south at 8 degrees. Above this package is an angular disconformity, beginning with 5 cm of laminar fine-sandy loam running parallel to the ground surface. Next is a 77-cm-thick package of laminar silty loam grading to massive loamy fine sand. A 2-cm-thick silt lens is found 6 cm below the top of this package. Overlying this package is a 3-cm-thick, subangular-to-blocky silty clay loam capped by 15 cm of massive fine sand grading to a loamy fine sand with a weakly developed A horizon.

3.3.3.9. 2014 Auger

Most of the 3.75 m of sediment recorded in the auger, located at 1,194.31 masl, consisted of fine-grained material, and much of the sediment recovered below 15 cm BS was too wet to complete texture by feel with a high degree of confidence. The lowest stratum was 16 cm of black loamy fine sand (Figure 3.18). Above this was 71 cm of a yellowish-gray gleyed clay containing redox concentrations. Next was a 107 cm bluish-gray clay containing black organic concentrations. Within this deposit were amorphously-shaped white tephra concentrations between 200-225 cm BS. Above this was a 94-cm-thick package of bluish-gray, gleyed clay deposits rich in organics with subangular structure in the lower 38 cm and massive structure in the upper 56 cm. The overlying 37 cm was a very wet, black, organic-rich clay. The unconsolidated sediment was capped by 35 cm of slightly denser, but still wet, sediment described as dark gray gleyed clay. The top 15 cm was a yellowish-brown moderately-compact sandy clay.

3.3.3.10. Summary of Cutbank and Auger Record

The cutbanks provided clear, easily accessible strata for study and interpretation identifying lake-level fluctuations. While the fine-grained sediments could be interpreted as low-flow or overbank conditions in the Walker River, for much of the last 5,000 years, the lake has been higher than the cutbanks studied and has undergone repeated rapid elevation crashes. The most recent historic recession resulted in river-channel downcutting revealing ancient lacustrine sediments as well as high-energy shoreline and fluvial deposits (see Adams 2007 for additional sediment package interpretations). As illustrated in the descriptions, the complexity of cutbank stratigraphy and number of transitions between coarse-grained sand/gravel deposits and fine-grained silt/clay deposits correlates strongly to the elevation of a given cutbank record. The highest cutbank (cutbank 1) has three distinct stratigraphic packages consisting of a coarsening-upward sequence capped with fine-grained material. This indicates a single transgression event where water-energy levels increased with shallower waters or increased fluvial energy, followed by low energy deposition associated with deep-water inundation.

As elevation decreases, sequence complexity increases as shown in the number of coarse-to-fine-grained transitions. Cutbank 2 has six sediment packages that alternate between coarse and fine deposits, suggesting three periods of change from shallow-water, high-energy depositional events to deep-water, low-energy depositional events. Cutbank 3 has nine sediment packages alternating from fine to coarse deposition. The sequence suggests a record of five deep-water, low-energy depositional events separated by four periods of shallow-water, high-energy deposition. Cutbank 4 has six sediment packages, alternating from coarse-to-fine-grained deposits, suggesting three high-energy, shallow-water events separated by three deep-water, low-energy depositional periods. Cutbank 5 has eight packages of alternating coarse-to-fine sediment changes with a final deposit of coarse material at the top. This indicates five periods of low lake levels interrupted by four periods of deep-lake inundation. Cutbank 6 has eight sediment packages, with the lowest 95 cm containing sandy gravels separated by two fine-grained clay deposits. Above this, abundant sand and sandy gravels are separated by a single, thin silt deposit. The full sequence consists of three sets of coarse-to-fine-grained sediment changes with a thick coarse deposit near the top of the profile. It indicates four periods of low-lake depositional periods separated by three, deep-lake depositional periods. The top massive silt may be eroded deep water deposits currently being impacted by aeolian erosion in the basin. Cutbank 7 is the deepest profile by over a meter and is separated into 10 distinct sediment packages. It is also the only cutbank containing two unique tephra deposits, indicating it may represent the longest continuous record of deposition of the cutbanks. Despite its length, the cutbank sequence is relatively straight-forward, with fewer transitions per meter. The lower 190 cm of the cutbank is most complicated, represented by five fine-grained deposits indicative of inundation and four coarse deposits evidencing either nearshore or shoreline contexts. The upper 354 cm contains several thick packages, with two coarse-grained deposits and two fine-grained deposits, indicating two extended nearshore/shoreline phases and two deep-water lake phases. Cutbank 8 has seven distinct sedimentary units separated into three sets of coarse-to-fine deposits capped with a final coarse-grained package, indicating three periods of inundation bracketed by four periods of shallow-lake deposition, or even shoreline formation at this location.

The 2014 Auger profile has only three distinct sediment packages, likely due to the nature of collecting data when using a bucket auger and the fact that most of the material was collected from below the current water table. This deep profile consisted largely of clay (~340 cm of the entire profile). A tephra was found at about 200 cm BS, just over halfway down the profile in the middle of the clay section. The lowermost 16 cm and uppermost 15 cm of the profile consisted of coarser deposits of sand and sandy loam, respectively. This pattern indicates two major depositional changes at this location, a change from a nearshore lacustrine setting to a relatively stable, deep-lake setting, and then back to a more shallow, nearshore setting. This profile is very different from all profiles observed in the cutbanks upstream along the lower Walker River. They consist largely of alternating sands and silts with intermittent clay deposits. The overwhelming signature of water-logged clays with decayed organics in the 2014 Auger profile is indicative of long-standing lake-bottom sediments. This is not surprising considering that it was excavated in the current delta area where the Walker River flows into the lake, and it is located approximately 24 km from the northern edge of the historic highstand shoreline. As such, prior to 1882 it was located in the middle of the lake. The upper 15 cm of sandy loam likely represents near-shore, shallow-water deposition associated with decreases in the level of Walker Lake during the past 15-25 years. The bottom 16 cm of sand may represent the last time this area was part of the littoral lake or river system prior to late Holocene transgressions.

3.3.4. Tephra Analysis

Full spectrometer results for the four analyzed tephra samples are shown in Appendix B (Tables B.1-B.8). These show the weight percents (wt %) for major elements and parts per million for trace elements. The results include both raw values and values corrected for halogens/O_2 content. Generally, comparisons of the geochemical analysis of the samples showed homogeneity between them. Of the 89 glass-separate analyses run, 21 were taken from the TB-1 tephra. Five of these were identified as outliers: two with high Cl values, one high in Al, one high in Ca value, and one with low overall spectrometer values. For the TB-2 tephra, 22 glass-separate analyses were run. One of these was identified as an outlier due to low K values. Twenty-three analyses were run on the TB-3 tephra, which had two outliers: one with a high Ca value and the other with low Fe. Finally, 23 glass separate analyses were run from CutTeph-3, returning no outliers.

While the analyses indicated geochemical homogeneity between the tephra samples, there is a slight difference between KO_2 and SiO_2 (Figure 3.19). The observed differences exclusively occurred between TB-3 and CutTeph-3. Despite their mutual difference, the KO_2 and SiO_2 values for both samples overlap those for the TB-1 and TB-2 tephras while at the same time partially overlapping one another. As a result, there is minimal evidence for unique differences in geochemistry between the four tephras studied.

The strong geochemical similarities combined with similar stratigraphic contexts indicate these samples are almost certainly from the same volcanic event. Each of the

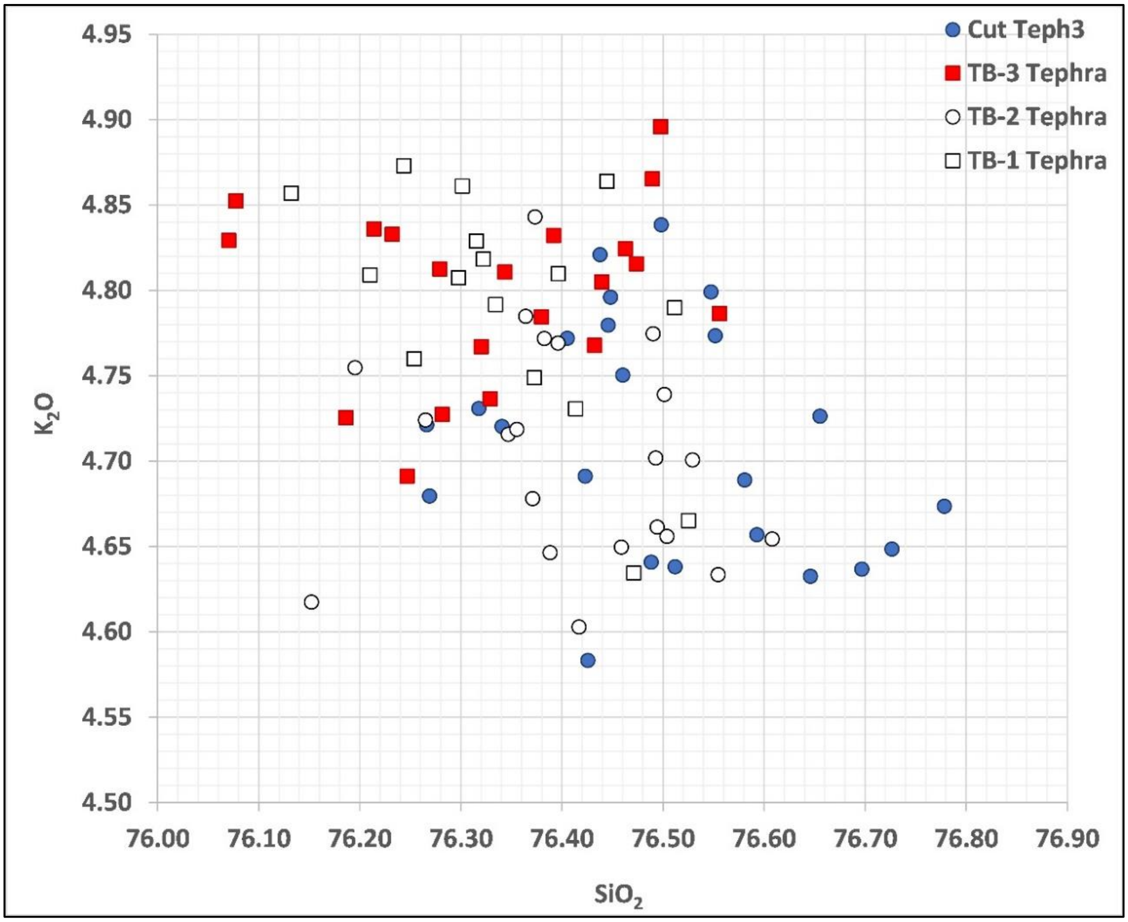

Figure 3.19. Graph showing the amount of KO2 and SiO2 by percentage of total chemical make-up. The comparison of these elements shows the most geochemical difference between the samples, particularly between the TB-3 tephra and CutTeph-3. The fact that this most dissimilar geochemical comparison maintains extensive sample overlap highlights the overall geochemical homogeneity among the tephra samples.

samples is surrounded by fine-grained, low-energy sediments, and only CutTeph-3, from a much higher elevation, has evidence of larger-grained sands or gravels above it (Figure 3.6). The correlation between geochemistry, stratigraphy, and context fit the standards of tephra correlation discussed by Kuehn et al. (2011) and Lowe et al. (2017). Based on the existing lake-level curve for Walker Lake (Figure 3.2; see also Adams and Rhodes

2019b), the radiocarbon dates collected below the tephra samples in the cores (see radiocarbon date discussion below), and the cutbank stratigraphy, the only event that could correlate to these tephras is the North Mono Eruption occurring at 650 cal BP (Bursik et al. 2014; Sieh and Bursik 1986). The next-earliest eruption, the South Mono Eruption, occurs at 1325 cal BP. For this eruption to correlate to the tephras, they would have had to be deposited below the sands containing the radiocarbon samples collected from the test block cores. Since this is not the case, we contend these tephra samples were deposited by the North Mono Eruption. Future geochemical analyses comparing these tephra samples to known North Mono and South Mono tephras will help confirm the samples' origin.

The tephra samples analyzed directly correlate to the other tephras found in cutbanks 2, 3, 5, the upper tephra in cutbank 7, the auger tephra, and the tephra from the 2015 test excavation. In the case of the auger and 2015 test excavation, the stratigraphic context is identical to the tephra material found in the submerged test blocks (the tephras were identified in fine-grained materials at a depth of ≤2 m with no coarse-grained material above them). Correlation between CutTeph-3 and the cutbank 2, 3, 5, and upper 7 tephras is less direct. These tephras in the cutbanks can be correlated for four reasons. First, with the exception of cutbank 7, they are all the only tephra in the recorded stratigraphy. Second, they are all located between 0.5-2.0 m from the surface. Third, they lie directly above coarser sediments, suggesting deposition shortly after a recession event. Finally, they are all capped by one or two sandy deposits, depending on elevation.

Comparably, CutTeph-3 was located between cutbanks 3 and 4, ~70 cm BS. The precise stratigraphic context of this tephra was difficult to clarify due to some erosion and sediment mixing; however, it was deposited between two fine-grained sediment packages. Above these, were two coarse-grained sediment packages, placing the tephra in a similar depositional context as the tephra in cutbank 3 and correlating it to the silt loam deposit located ~80 cm BS in cutbank 4. Taken together, these stratigraphic contexts provide evidence for linking CutTeph-3 and the tephras in cutbanks 2, 3, 5, and upper cutbank 7. Because the upper tephra in cutbank 7 appears to be tied to the North Mono Eruption, there is also some temporal context for the second, lower tephra in cutbank 7. First, based on our interpretation of the upper tephra deposit, this lower deposit must pre-date the North Mono event. Second, past research has shown that the South Mono tephra was deposited across the Walker Lake basin prior to the North Mono tephra and that no volcanic event occurred in the region between these two eruptions (Bursik et al. 2014; Sieh and Bursik 1986). Therefore, we argue the lower cutbank 7 tephra is likely the South Mono tephra, and additional research will help definitively correlate the two.

3.3.5. Radiocarbon Dating

3.3.5.1. Radiocarbon Age Results

A total of 13 radiocarbon samples were selected for dating, but only 10 had enough carbon to provide meaningful radiocarbon dates (Table 3.1**)**. The sandy, stratum I sediments from the TB-1 cores were searched for organic materials with the intent of providing temporal context of the associated depositional event. Unfortunately, only two organic samples were identified, both from the lowest sub-stratum, Ia. An early date of 2460 ± 25 (PSU-5088) ^{14}C BP was returned on a fish bone. The second date returned was modern, 10 ± 15 (PSU-4948) ^{14}C BP, from a small wood fragment. The modern date suggests the sample was introduced into the core during its recovery. Because only one acceptable date was recovered from this stratum, it is possible that fish bone is old material that was redeposited into TB-1:Ia. This is unlikely, however, as the stratum is interpreted as littoral sediments deposited across a prograding delta, providing no clear environmental context that would have allowed old lacustrine material as delicate as a fish bone to be reworked and redeposited into the coarse-grained sands.

For dating, we identified one sample from stratum II in each of the three cores taken from TB-2. These were 910 ± 15 (PSU-4551), 965 ± 15 (PSU-4554), and 920 ± 15 (PSU-4555) ^{14}C BP, which overlap at 2-σ standard deviation. The dates were obtained on small twig fragments and are associated with the loamy sand capping the deeper sand deposit of stratum I. Obtaining three dates that overlap at 2-σ standard deviation demonstrates this stratum represents the same depositional event in each core.

Table 3.1. Radiocarbon samples collected from test block cores.

Radiocarbon Samples							
Lab No.	**C14 BP**	**Cal BP (median)**	**Cal BP (2 σ range)**	**Material**	**Core**	**Stratum**	**Depth (BS)**
PSU-5088[c]	2460 ± 25	2229	2,291-2158	Fish Bone	TB-1, SW Core	Ia	278 cm
PSU-4948	10 ± 15	NA	NA	Wood	TB-1, SW Core	Ia	279 cm
PSU-4551	910 ± 15	865	905-741	Wood	TB-2, NE Core	II	144.5 cm
PSU-4554	965 ± 15	847	922-797	Wood	TB-2, S Core	II	216 cm
PSU-4555	920 ± 15	869	910-777	Wood	TB-2, Central Core	II	214 cm
PSU-4557	965 ± 20	848	925-793	Wood	TB-3, SW Core	I	261 cm
PSU-4553	985 ± 15	908	930-799	Wood	TB-3, NE Core	IIIa	206.5 cm
PSU-4556	970 ± 15	850	924-797	Wood	TB-3, SW Core	IIIa	240 cm
PSU-4552	925 ± 15	861	910-785	Wood	TB-3, Central Core	IIIc	236 cm
PSU-4683	840 ± 20	735	787-700	Wood	TB-3, SW Core	IIIc	235.5 cm

[a]Radiocarbon samples dated at the Penn State AMS Radiocarbon Laboratory.
[b]14C dates calibrated using the Intcal20 curve in the online version of OxCal 4.4 [Ramsey 2020; Reimer et al. 2020].
[c]δ13C (‰)= -17.89, δ15N (‰)= 8.09, %C= 22.64, %N= 8.39, C:N= 3.15.

I collected five dates from small twigs in the TB-3 cores. One was collected from stratum I, the lowest sand-rich stratum in the southwest core, dating the lowest-observed deposition of coarse-grained sediments in the TB-3 cores to 965 ± 20 (PSU-4557) ^{14}C BP. The other four dates are associated with stratum III. These allowed for temporal comparison between the stratigraphically-correlated upper sections of this coarse-grained depositional event. Two came from sub-stratum IIIa in the northeast and southwest cores, 985 ± 15 (PSU-4553) and 970 ± 15 (PSU-4556) ^{14}C BP, which overlap at 1-σ standard deviation. I collected the last two samples from sub-stratum IIIc in the center and southwest cores. They produced the dates of 925 ± 15 (PSU-4552) and 840 ± 20 (PSU-4683) ^{14}C BP, respectively. Unlike the other cross-core samples from TB-3, these do not overlap at 2-σ standard deviation.

These dates demonstrate temporal association across the strata within each block. Dates collected from stratum II in TB-2 and stratum I and sub-stratum IIIa in TB-3 are closely correlated, all overlapping at 2-σ standard deviation. The older of the two dates from sub-stratum IIIc in TB-3 is also congruent with these. The seemingly incongruent, youngest date from sub-stratum IIIc in TB-3 (840 ± 20 ^{14}C BP), however, does overlap at 2-σ with the two youngest dates (910 ± 15 and 920 ± 15 ^{14}C BP) from stratum II in TB-2. These results indicate that sub-stratum Ia in TB-1 dates the deposition of sand, presumably in a nearshore or shoreline context, at about 2,200 cal BP. Stratum II in TB-2 and strata I, IIIa, and IIIc in TB-3 are associated with a relatively short period of deposition of nearshore and shoreline sands around 860-800 cal BP.

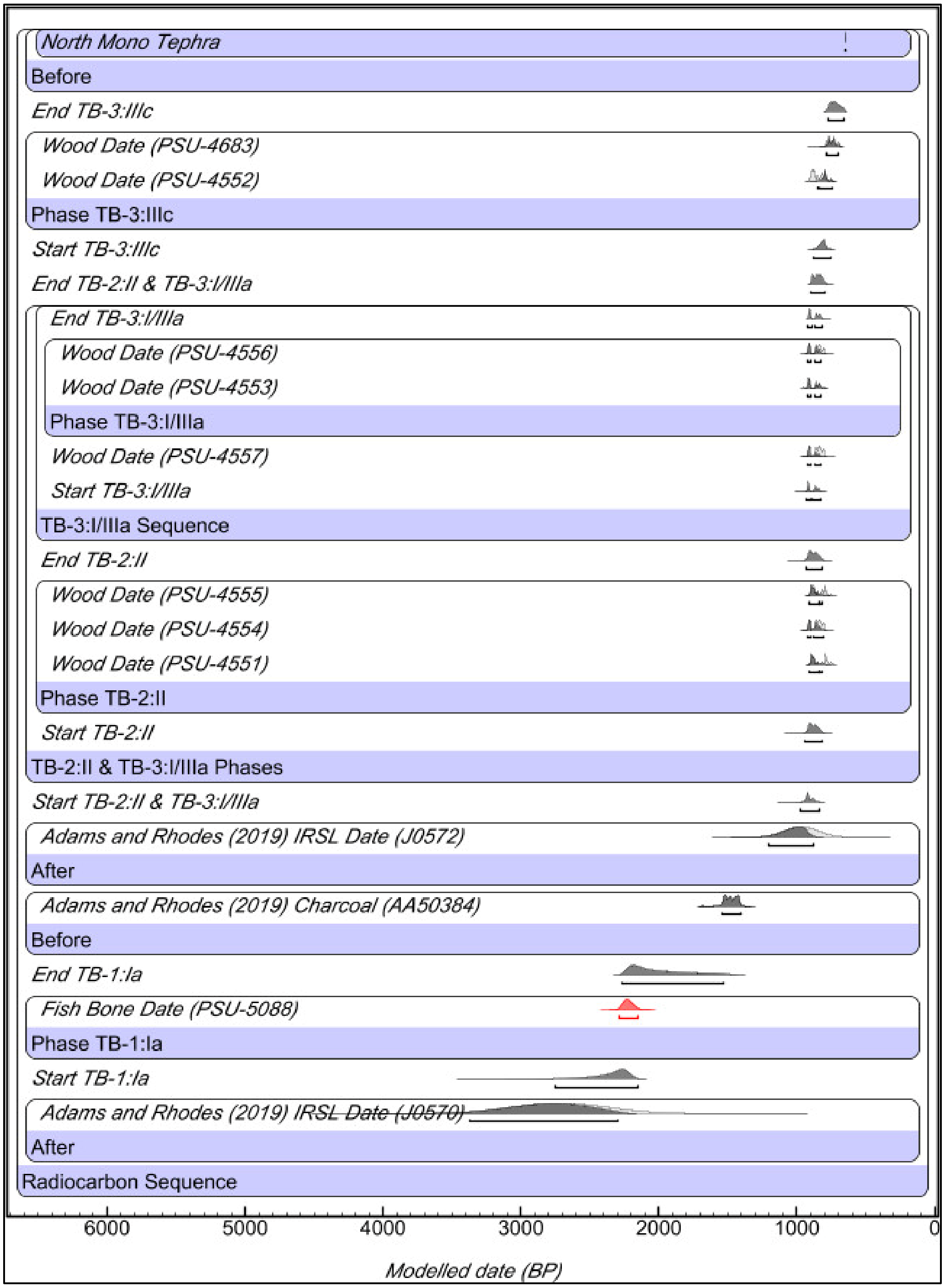

Figure 3.20. Calibrated and modeled radiocarbon ages and sedimentation periods based on ages and stratigraphy from excavation block cores (this study) and partially-constrained by three previously-published dates (Adams and Rhodes 2019b). The radiocarbon range represents the date calibrated using a 300-year reservoir effect.

Table 3.2. Results table for the Bayesian statistical model for sedimentation based on the radiocarbon record.

Name	Unmodelled (BP)			Modelled (BP)			Indices Amodel=103.7 Aoverall=96.1				
	from	to	%	from	to	%	Acomb	A	L	P	C
North Mono Tephra				651	650	95.4					100
Before	...	1300.55	95.4								
End TB-3:IIIc				778	655	95.4					99.7
Wood Date (PSU-4683)	780	689	95.4	790	697	95.4		90.7			99.8
Wood Date (PSU-4552)	910	785	95.4	852	740	95.4		73.1			99.9
Phase TB-3:IIIc											
Start TB-3:IIIc				875	755	95.4					99.7
End TB-2:II & TB-3:I/IIIa				902	797	95.4					99.1
End TB-3:I/IIIa				922	815	95.4					98.8
Wood Date (PSU-4556)	924	797	95.4	924	825	95.4		116			98.8
Wood Date (PSU-4553)	930	799	95.4	924	826	95.4		84.5			98.8
Phase TB-3:I/IIIa											
Wood Date (PSU-4557)	925	793	95.4	925	830	95.4		109			98.9
Start TB-3:I/IIIa				936	826	95.4					98.9
TB-3:I/IIIa Sequence											
End TB-2:II				937	812	95.4					99.4
Wood Date (PSU-4555)	910	777	95.4	912	814	95.4		105			99.6
Wood Date (PSU-4554)	922	797	95.4	925	808	95.4		102			99.2
Wood Date (PSU-4551)	905	741	95.4	910	812	95.4		102			99.6
Phase TB-2:II											
Start TB-2:II				937	812	95.4					99.4

Table 3.2. Continued

Name	Unmodelled (BP)			Modelled (BP)			Indices Amodel=103.7 Aoverall=96.1				
TB-2:II & TB-3:I/IIIa Phases											
Start TB-2:II & TB-3:I/IIIa				972	836	95.4					98.3
Adams and Rhodes (2019b) IRSL Date (J0572)	1206	726	95.4	1209	884	95.4		108			99.2
After	1187.5	...	95.4								
Adams and Rhodes (2019b) Charcoal (AA50384)	1546	1402	95.4	1546	1401	95.4		99.6			99.5
Before	...	411.8	95.4								
IntCal20											
End TB-1:Ia				2266	1540	95.4					98.5
Fish Bone Date (PSU-5088)	2291	2158	95.4	2289	2148	95.4		98.3			99.7
IntCal20											
Phase TB-1:Ia											
Start TB-1:Ia				2747	2150	95.4					98.8
Adams and Rhodes (2019b) IRSL Date (J0570)	3397	2037	95.4	3382	2293	95.4		106			97.2
After	-191.5	...	95.4								
Radiocarbon Sequence											

3.3.5.2. Modeling Calibrated Radiocarbon Dates

The results of the Bayesian model are shown in Figure 3.20 and Table 3.2. This model integrates the dates for lake level changes shown in Adams and Rhodes (2019b) to model the sequence of depositional events, and as such I discuss both the new dates and those from previous work. The model shows that after the depositions of a beach ridge at 1,257 masl, dated between 3,400-2,040 cal BP using infrared stimulated luminescence (IRSL) (Adams and Rhodes 2019b), the sands in stratum I in TB-1 (TB-1:Ia) were deposited at 1180 masl or lower. Deposition started by 2,289-2,148 cal BP or the modeled age range of the fish bone from this study. The entire modeled 2-σ age range for deposition of stratum Ia in TB-1 (TB-1:Ia) from beginning to end is wide, 2,747-1,540 cal BP (Figure 3.19). Adams (2007) uses charcoal deposited in in a fluvial system at 1,247.5 masl to estimate a Walker Lake highstand at ~1,250 masl at 1,500 cal BP (Adams and Rhodes 2019b). If correct, then deposition of TB-1:Ia should have ceased by 1,570-1,410 cal BP. The location of the sands in TB-1:I seems stratigraphically similar to the location of the sand in TB-2:II and TB-3:I and III; however, the age of these materials is separated by nearly 1,400 years (see discussion of TB-2 and TB-3 dates below). The different ages indicate the presence of a disconformity above TB-1:I resulting from an erosional event that removed the sands that would have been deposited above this stratum.

Based on the modeled IRSL date from a beach ridge at 1,253 masl, the subsequent phases must occur after 1,209-884 cal BP (Adams and Rhodes 2019b). The phase combining stratum II in TB-2 (TB-2:II) and strata I and IIIa in TB-3 (TB-3:I/IIIa) show extensive overlap between these depositional events. The deposition of TB-2:II has a modeled 2-σ age range of 937-812 cal BP. Deposition of TB-3:I/IIIa has a modeled 2-σ age range of 936-815 cal BP. The deposition of TB-2:II and TB-3:I/IIIa combined has a modeled 2-σ-boundary age range of 972-797 cal BP. These results indicate the deposition of these strata was roughly contemporaneous, but acknowledge the potential for more time to account for all of them. In all likelihood these sediments correspond to the same depositional event. The final modeled phase, the deposition of stratum IIIc in TB-3 (TB-3:IIIc), has a 2-σ age range of 875-655 cal BP. The results indicate there is potential for temporal overlap between the deposition of TB-2:II and TB-3:IIIc. However, because TB-3:I and IIIa have a near exact overlap with TB-2:II and both must precede TB-3:IIIc, I argue TB-3:IIIc was deposited slightly after TB-2:II. Overall, there is excellent agreement between the unmodeled and modeled calibrated ranges: A_{model}=103.7 and $A_{overall}$=96.1. The deposition of all four of these sub-strata must have been quite rapid because they show a great deal of overlap in their modeled boundaries, and likely represent a single major episode of lake recession at or below the location of the associated test block sediments (~1,180 masl).

3.4. Discussion: Combining Proxy Records to Interpret Lake History

3.4.1. Submerged Records of Lake History

As discussed in the results, the interpretations of the sub-bottom features and stratigraphy are based on well accepted standards for submerged remote-sensing and geophysical survey. Additionally, interpretations of the upper 2.5 m of reflections as lake sediments and Reflection 1 as a sand were verified by the sediments recovered during excavation and coring. Combined, the sub-bottom results and excavation blocks provide a strong foundation for interpreting the lake record preserved below the waterline. These data reveal information about possible lake transgressions and recessions as well as changing depositional environments within the basin. Feature 1 provides evidence for preserved higher-energy sands, shown in Reflection 1, being deposited across the surface of a prograding delta at the northern end of the lake (Figures 1.1 and 3.8). The association between Reflection 1 and sand deposits was verified in the cores as strata I:TB-1, II:TB-2, I:TB-3, and III:TB-3. The relatively smooth surface and consistent angle of the sand package (Figure 3.8) suggests that these sediments represent littoral or shallow-water sediments deposited as the lake shoreline moved across the delta. Reflection 1 likely represents sands deposited reworked during the most recent transgression across an elevations of roughly 1,178-1,179.5 masl. I note that Reflection 2 has a similar depositional pattern along Feature 1 and below Reflection 1. This suggests that Reflection 2 may represent an earlier transgression or recession event that deposited sediments on the surface of the delta. Reflection 2, however, is less consistent, suggesting its deposition may have been less stable or that the feature was impacted by subsequent erosional events.

The other two primary features identified in the sub-bottom data, Features 2 and 3, most likely represent fluvial downcutting events that occurred when lake level was below ~1,180 masl. These features point not only to low lake levels, but also evidence the presence of fluvial depositional environments. The features express common forms found in submerged and buried channels. As such they would have been associated with low lake levels and provide additional details of the Walker Basin during dry periods or when the river flowed into the Carson Sink. Additional survey and research focused on other reflections within the sub-bottom profiles, such as those below Reflection 2 and potential small rivulets observed in Reflection 2 on the western edge of the sub-bottom transects may further reveal the broader and older lacustrine and fluvial history of the basin.

The presence of features in the sub-bottom profiles provides evidence for landform preservation during environmental changes in the Walker Lake basin. By testing the sediments at these locations, we are able to better understand the history of Walker Lake. The cores recovered from the 2017 test blocks demonstrated that Reflection 1 does, in fact, consist of coarse sand deposits covered by 2-4 m of fine-grained deep-water sediments. The tephra samples and organic materials recovered from the cores provided chronological context for the depositional environments investigated in the sub-bottom survey, excavations, and coring. These dates are further discussed below to refine the lake-level history. Finally, the organic material recovered in the screen during excavations revealed useful information about the local floral and faunal environments, allowing for the reconstruction of basin environmental productivity during the last millennium. Overall, these efforts demonstrate a rich record of buried preserved features, sediments, and organic materials within Walker Lake that is essential for understanding the history of the Walker Lake basin environment.

3.4.2. A Revised History of Walker Lake for the Late Holocene

The revised lake history is based on the test-block excavations, augering, and cutbank observations made during my fieldwork. The sub-bottom profiles, test-block excavations, and the auger demonstrated the presence of more than 2 m of deep-water, low-energy sediments across the northern half of the lake. The North Mono tephra was consistent across the submerged sediments and often well preserved with a fining upward sequence of ash ranging in size from medium sand to silt. Below the deep-water sediments, test blocks 1, 2, 3, and the auger contained coarse-grained, high-energy sediments associated with shallow-water, near-shore or littoral depositional contexts. Organic material collected from these sediments in the test blocks allow them to be placed in chronological context.

The cutbanks provide a more complex record with little chronological control. However, the location of the North Mono Tephra in cutbanks 2, 3, 5, and 7, along with a second, deeper tephra in cutbank 7 associated with the earlier South Mono Eruption, allows cutbank sequences to be contextualized. These records point to two high-energy, shallow-water or littoral depositional events after the North Mono tephra was deposited in cutbanks 2, 3, and 5. Only one such event is recorded above the upper tephra in cutbank 7. The tephra is also deposited in different materials across these cutbanks, with the cutbank 2 tephra associated with the coarsest material, suggesting the lake was near this level during the North Mono Eruption. Finally, I note at least two thick high-energy, shallow-water deposits between the South Mono and North Mono eruptions in cutbank 7, likely associated with lowstands at 1,050 and 800 cal BP. There is an earlier, thinner high-energy deposit in this sequence, perhaps representing a shorter, undated recession not noted in the lake curve. Below I revise the lake-level curve and generalize the Walker Lake basin's environmental history according to these details.

The adjustments to the Walker Lake curve builds on Adams' (2007) model, which was revised by Adams and Rhodes (2019b) (Figure 3.2). The dataset presented here is focused on lake history from ~2,500 cal BP to the historic high stand. The revised curve is shown in Figure 3.21.

The earliest adjustment to the curve is during the dramatic drop in lake level 2,500-2,000 cal BP (Adams 2007). The original curve places a question mark at this recession, indicating that past researchers were uncertain how low the lake may have fallen. Fortunately, the date associated with the fish bone in TB-1 was found in a sand deposit, representing a littoral context indicative of this recession event. Further, TB-1 was placed at the Reflection 1 highpoint east of Feature 1, allowing association between the block and the upper elevations of the Reflection 1 transgression/recession deposits across the prograding delta. By following Reflection 1 to its lowest elevations in Feature 1, the reflection levels off at ~1,178 masl. This provides the first estimate for the lower elevation of the recession 2,500-2,000 cal BP, during which the lake receded to as low as 1,178 masl and maybe even lower.

The next adjustment is associated with the lake recession post-dating the highstand at 1,500 cal BP and the contemporaneous South Mono Eruption dating to 1,325 cal BP (Adams 2007; Bursik et al. 2014; Sieh and Bursik 1986). As discussed in the results, the lower tephra in cutbank 7 is interpreted as dating to this event. This

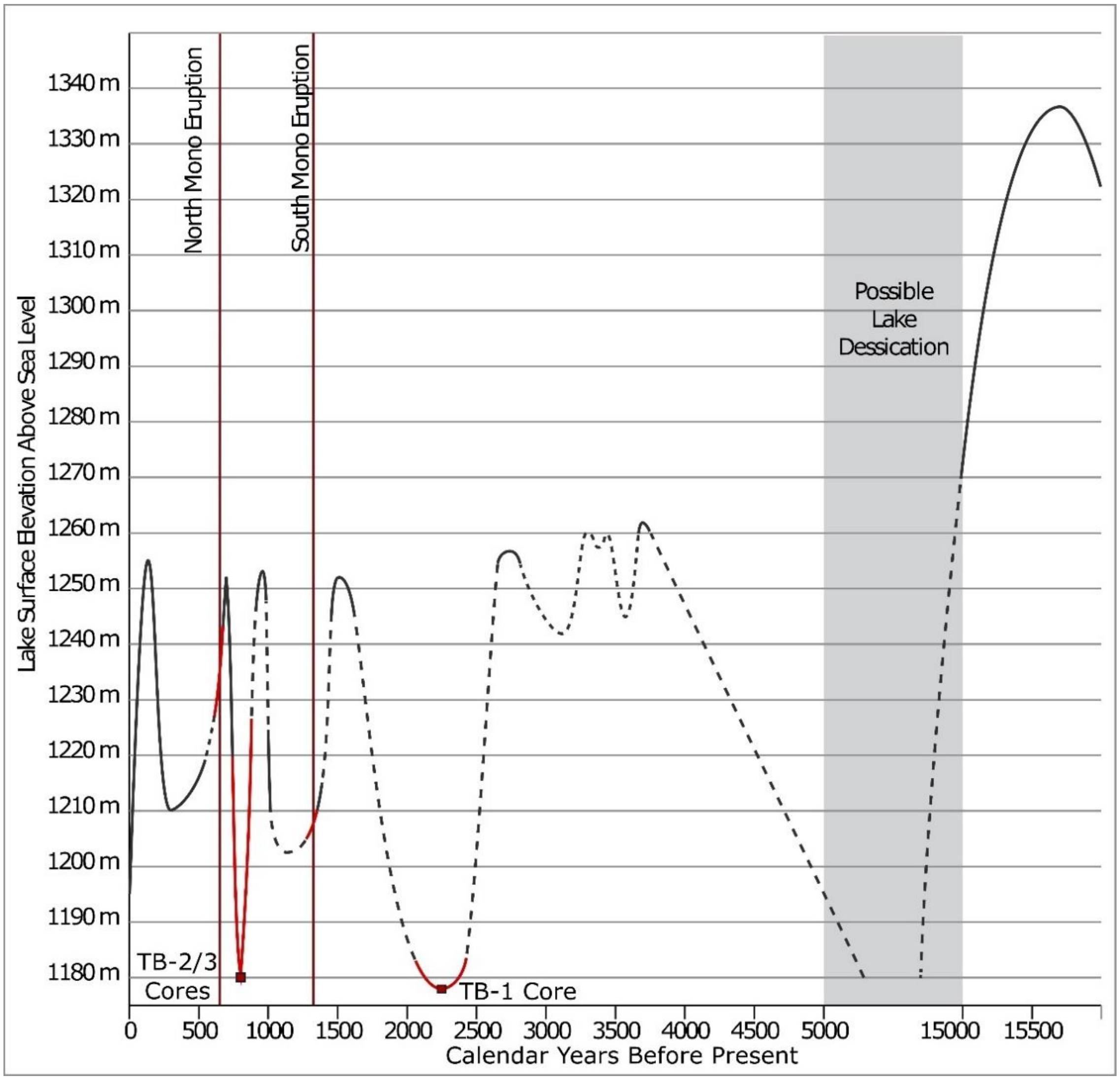

Figure 3.21. Revised curve based on new radiocarbon dates and tephra observations in the cutbank record.

tephra material was found in fine loamy sand indicating it was deposited when the lake elevation at cutbank 7 was in a near-shore or littoral context and lake level was <5 m above 1,203.7 masl (Adams 2007:table 2). If the lake were deeper, the sediment associated with the tephra would have had a higher silt or clay content and little to no sand. If the lake elevation were below 1,203.7 masl, the tephra should be found in association with coarser-grained sediments (i.e., medium sands) or not be preserved at all. Based on these observations, the lake can be placed roughly 5 m above the South Mono tephra in cutbank 7, at ~1,208.7 masl during the South Mono Eruption at 1,325 cal BP.

Another important adjustment this study makes to the curve is between 950-700 cal BP. Adams and Rhodes (2019b) built this portion of the curve based on multiple ages. First a IRSL age (Sample #J0572) from ~960 cal BP was derived from sediment at 1,253 masl (Adams and Rhodes 2019b). Second, four charcoal and plant dates in wave rippled sands place the lake level between 1209-1223 masl at 940-955 cal BP. Third, a charcoal age of 930 cal BP in fluvial deposits at 1,209 masl suggests lake level was falling at this time. Fourth, another charcoal sample in wave-rippled sands dating to 780 cal BP is at 1,224 masl. Adam's and Rhodes (2019b) resulting curve shows that after the 1,202-masl lowstand dating to 1,050 cal BP, lake level rose to 1,253 masl by 960 cal BP. The lake subsequently dropped to an elevation of 1220 masl by ~790 cal BP.

The chronology for the excavations in Walker Lake reported here indicates a slightly different sequence of elevations post-dating 960 cal BP. The dates from the sands in TB-2 point to a shallow-water or littoral context associated with a lake lowstand around 860 cal BP. The sequence in TB-3 suggests two shallow-water or littoral depositional events: an early event between 920 and 850 cal BP and a later event between 850 and 750 cal BP. The lower, earlier deposit in TB-3:I consists of fine-grained, low-energy sediments interdigitated with coarse-grained, high-energy sands.

This suggests a depositional context in which lake depth fluctuated around 5 m above this elevation (1,180 masl), allowing for a period of both fine and coarse-grained deposition. Above TB-3:I, the higher TB-3:III deposit consists of a fining-upward sequence of sand to sandy clay. This suggests a littoral depositional context and that lake levels fell before quickly rebounding after the deposition of TB-3:IIIa. Based on these observations, I argue that after 960 cal BP, lake level fell to within 5 m of 1,180 masl by ~890 cal BP, during which it fluctuated, depositing sands and sandy clay loam. This was followed by a slight increase in lake level, depositing the clay in TB-3:II. The lake then fell to at least 1,180 masl between 860-800 cal BP, after which it began transgressing, likely passing 1,185 masl by ~750 cal BP.

Above the current water level, cutbanks 3, 5, and 7 provide further evidence for this sequence. In cutbanks 3 and 5, the North Mono Tephra and the associated fine-grained sediments directly overlie extensive coarse-grained sands and gravelly sands. These deposits likely resulted from the recession associated with TB-2 and TB-3 sands. In cutbank 7, the two clear transitions between sand and fine-grained deposits occurring between the South Mono and North Mono tephras also reflect the proposed curve. The thickness of the two sandy deposits implies the earlier recession was less pronounced because the sand deposits are thinner, while the later event associated with the TB-2 and TB-3 dates was much more extensive, allowing for abundant, prolonged sand deposition. Surprisingly, cutbank 2 does not show a similar sequence. Instead, the North Mono tephra caps only fine-grained sediments. This suggests that either more silt and clay was deposited here during the highstand at 690 cal BP or no sands are preserved here from the recession at 860-800 cal BP.

Finally, observations made in cutbanks above the waterline allow an estimate of lake level during the North Mono Eruption at 650 cal BP. Sediments at and above the North Mono Tephra in cutbank 2 indicate that the lake was between 1,230-1,235 masl at 650 cal BP where the tephra material was deposited in shallow near-shore or littoral deposits (Adams 2007). Below cutbank 2, the North Mono Tephra is found in fine-grained deep-water deposits in cutbanks 3, 5, 7, the auger, and all of the excavation blocks. I note, however, that in cutbank 3, the lower 3 cm of the tephra is in sands while the upper 6 cm is in low-energy, fine-grained material. In cutbank 5, most of the tephra is in low-energy, deep-water sediments, but its upper portion is associated with fine sands. In cutbank 7, the fine-grained material containing the tephra is capped by fine sands. These data provide evidence that the lake was already receding when the tephra was deposited, eventually reaching a lowstand of 1,210 masl at 300 cal BP (Adams 2007).

These lake-level adjustments provide useful information for previous lake-level curves and help address questions about changes to the lake's elevation. As discussed above, correlation between the age of sands containing the fish bone material and previous research indicative of low lake levels between 2,500 and 2,000 cal BP provides mutually supportive evidence for a lake lowstand at this time. The elevation estimate at 1,178 masl or lower is in agreement with Benson et al.'s (1991) position that the lake approached desiccation at this time rather than the suggestion by Berelson et al. (2009)

that the lake did not drop below 1,200 masl. Further, the 1,208 masl lake level correlated to the South Mono Eruption agrees well with a 1,281 cal BP charcoal date from fluvial deposits at 1,212 masl reported by Adams (2007). He does not report another date indicative of lake levels above this elevation until 954 cal BP where another charcoal sample was collected in wave rippled sands at 1,223 masl. As such, lake level stayed below 1,212 masl from at least 1,325-954 cal BP.

This sequence, however, further challenges the curve presented in Adams and Rhodes (2019b). The 1,253 masl highstand dated to 960 cal BP modeled from an IRSL date (J0572) directly contradicts samples Adams (2007) collected dating from 987-873 cal BP indicating lake level was never above ~1,223 masl during this time. Within this sequence, the sample at 1,223 masl (Beta-183893) is an outlier relative to six samples dating between 1,281-873 cal BP that place the lake at or below 1,212 masl. This suggests that the lake never rose above 1,212 masl after 1325 cal BP. In addition, the curve shows the highstand at 960 cal BP as a uniquely sharp peak (Figure 3.2; see also Adams and Rhodes 2019b:figure 4). Based on the contradictory nature of the highstand at 960 cal BP when compared to 14 radiocarbon dates indicating lake level was at or below 1,212 masl from 1,281-735 cal BP, it is more parsimonious to reject this IRSL data. In fact, Adams and Rhodes (2019b) *refrain* from including three IRSL dates in their curve that contradict other, lake-level elevations, some of which are less-well sampled (i.e., samples J0569, J0571, and J0573). As such, rejecting the 960 cal BP sample (#J0572) is not unprecedented. Figure 3.21 further illustrates how much the 960 cal BP highstand and the subsequent recession at 860-800 stand out as outliers.

By removing the 960 cal BP highstand, the curve shows lake level may have fluctuated from ~1,202-1,212 masl between 1,325 and 860 cal BP (Figure 3.22). During these fluctuations the interdigitated coarse and fine material in TB-3 stratum I, dating between 925-793 cal BP, could have been deposited along with the fine material in TB-3 stratum II. Around 860 cal BP lake level dropped to 1,180 masl where it remained until transgression began after 800 cal BP. Finally, the proposed lake elevation at 1,235 masl dating to 650 cal BP generally agrees with the evidence for lake transgression after 800 cal BP leading to a proposed highstand above 1,224 but below 1,252 masl at 700 cal BP. Figure 3.22 indicates this is another abrupt transgression, with Adams (2007) placing the highstand at 1,255 masl. It is important to consider that this high-stand elevation is based on hydrographic modeling and a radiocarbon date on charcoal collected from fluvial deposits (Adams 2007; Adams and Rhodes 2019b). As such, the highstand elevation at 700 cal BP is not well established, and since it is anchored by a single radiocarbon date from fluvial deposits, it may have been lower, closer the 1,235 masl lake elevation associated with the North Mono eruption. Additional research would help to test the 700 cal BP transgression elevation and determine if sharp changes in lake level actually occurred in the Walker Basin.

While some of the changes to the curve made here are minor, others, such as the dramatic lowstand elevations at 2,200 cal BP and between 860-800 cal BP provide important amendments to the curve that help clarify the magnitude of lake-level shifts

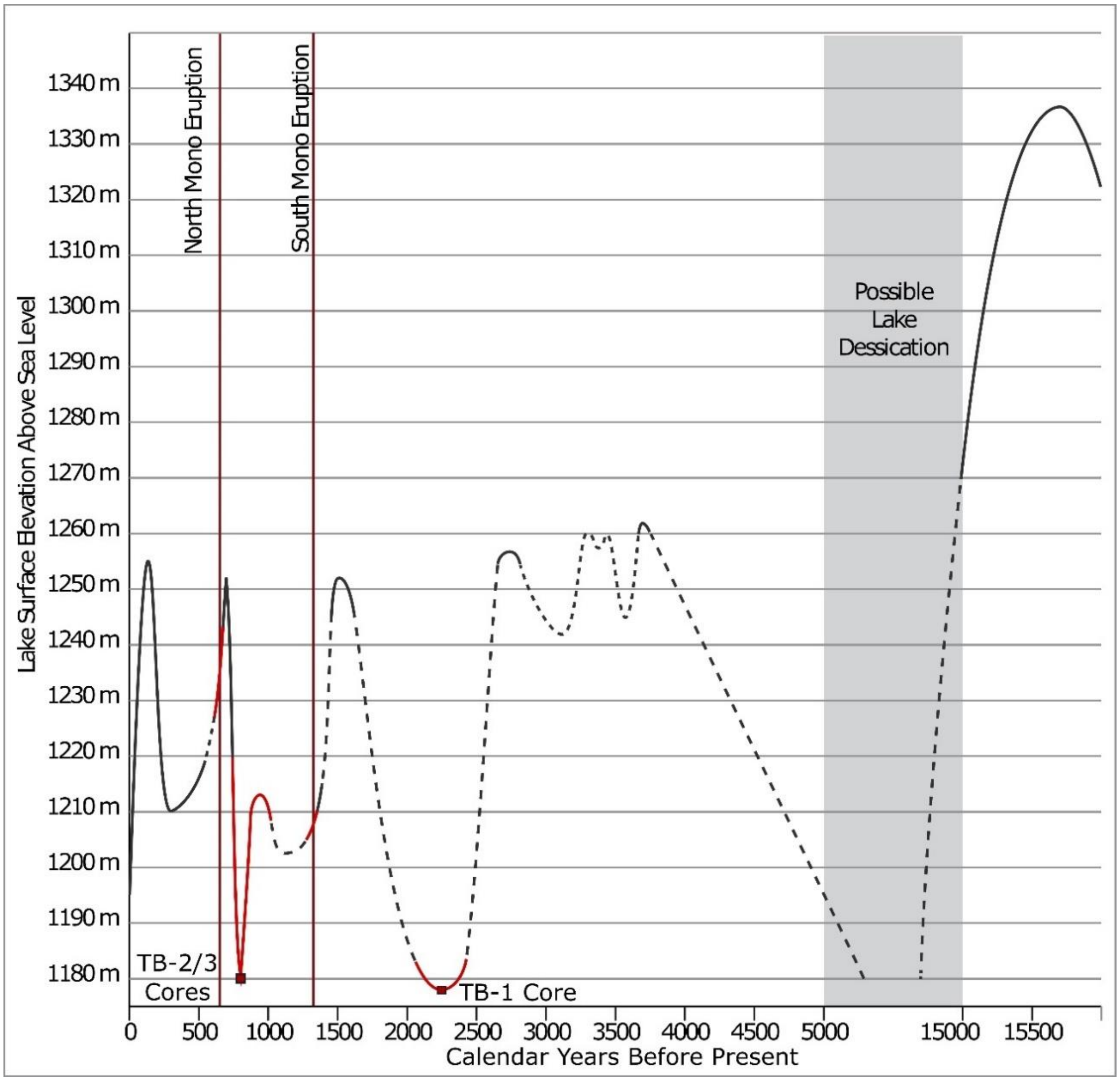

Figure 3.22. Modified lake-level curve for Walker Lake without the 966 cal BP highstand proposed by Adams and Rhodes (2019b).

and the extreme landscape changes that occurred in the WLB during the late Holocene. Overall, these datapoints are invaluable for building a more precise curve, which will further benefit from continued investigations.

3.4.3. Comparing Walker River Direction, Local Climate, and Lake Levels

The submerged sedimentological evidence for lowstands, sub-bottom reflections indicative of terrestrial, littoral, or near shore environments, and the changes presented for the lake level curve must be correlated to broader environmental changes in the region to fully understand this study's contribution to the field. This also provides a context in which to consider the question of mechanisms for lake change. In other words, did these lake-level changes result from shifts in climate, Walker River avulsions to Carson Sink, or both? Ultimately, this discussion places the new data presented here in a broad regional context and better demonstrates their implications.

The proposed correlation between Walker Lake water levels and river diversion into the Carson Sink implies a relationship between lake levels in the two basins. If Walker River is flowing into the Carson Valley during low lake levels in the Walker Basin, then Carson Sink should see increased lake elevations. In contrast, high lake levels in the Walker Basin should generally correspond to lower lake levels in Carson Sink. It is important to note that high evapotranspiration rates of water in the Carson Sink may mean that even with additional water flow, water in the valley may often be limited to a shallow marsh. Conversely, high precipitation rates across the Great Basin may result in high lake levels at both Walker Lake and the Carson Sink. Nonetheless, the correlation between lake levels in the two basins is an important line of evidence.

Carson Sink highstands occur at 2,700-2,350, 1,940-1,730, 1,820-1,570, 1520-1,310, and 910-660 cal BP. Only two of these overlap periods of low elevations in Walker Lake (2,700-2,350 and 910-660 cal BP) (Adams and Rhodes 2019b). The other age ranges instead overlap periods of relatively high lake levels during Walker Lake transgression or earliest recessions. This pattern suggests that lake levels in Carson Sink were controlled by environment rather that additional input from the Walker River. While this evidence does not refute periods of river avulsion to the north, the current evidence for high water levels in Carson Sink does not clearly correlate to low Walker Lake levels and Walker River direction does not appear to be the primary factor dictating Carson Sink lake levels. The question still remains: did river direction dictate Walker Lake levels?

Local environmental evidence for the Carson Sink and other nearby valleys clearly shows evidence for changing climate regimes from 2,500 cal BP onward. Based on study of several proxy records from several locations in the Great Basin, the late Holocene saw a dry period from 2,800-1,850 cal BP (Mensing et al. 2013), which correlates to the 2,200 cal BP lowstand in Walker Lake and the modeled low lake level pre-dating lake transgression beginning at 1,900-1,800 cal BP (Adams and Rhodes 2019b). Carson Sink, meanwhile, had two highstands during this dry period: at 2,700-2,350 and at 1,940-1,730 cal BP. In the Pyramid and Winnemucca basins to the north, lake levels dropped to extreme lows at 2,500 cal BP before transgressing 20 m by 2,100 cal BP, and then another 10-15 m during the next 1,000 years (Adams and Rhodes 2019a). In Mono lake, there is no clear record of the late Holocene dry period, but lake levels do fall from their mid-Holocene highstand at 3,700 cal BP to the subsequent lowstand at 1,800 cal BP during this period (Stine 1990). In contrast, Owens Lake to the south sees transgression during the early part of the late Holocene dry period, reaching its late Holocene highstand at 2,500 cal BP. The then recedes for the next 1,500 years (Bacon et al. 2006). Lake levels across the western Great Basin from Owens Lake north to Pyramid and Winnemucca Lakes evidence low lakes coeval with the Walker Lake lowstand at ~2,200 cal BP. These data, combined with the multiple proxy records discussed by Mensing et al. (2013), strongly support a climatic cause for lake recession at this time in the Walker Lake Basin.

Beginning at the Walker Lake highstand at 1,500 cal BP and extending to the period of low lake elevations from ~1,325-700 cal BP, there are mixed climatic signals across the region. In the Carson Sink, highstands occur 1,520-1,310 and 910-660 cal BP (Adams and Rhodes 2019b). In the Pyramid and Winnemucca basins, lake levels follow a similar pattern to Walker Lake, with transgression continuing a little longer, until 1,100 cal BP, followed by a period of minor recession during the MCA (1,150-700 cal BP) (Adams and Rhodes 2019). At Mono Lake, the record reflects the Carson Sink lake levels. The lake generally rose, with some fluctuation from 1,800 to 1,350 cal BP when a highstand occurred. This was followed by lake recession and a low stand at 950 cal BP, another highstand occurred at 860 cal BP, and a last recession and lowstand occurred around 680 cal BP (Stine 1990). At Owens Lake, the level record is more direct, with lake level gradually falling from 2,500-1,000 cal BP followed by a dramatic drop during the MCA (Bacon et al. 2006).

Given regional lake levels, higher precipitation resulted in the Walker Lake highstand at 1,500 cal BP, which corresponds to a period of generally rising water levels across the western Great Basin, north of Owens Lake. The low levels in Walker Lake after 1,500 cal BP are also reflected in Pyramid, Winnemucca, and Mono lakes and the Carson Sink where lake levels generally remain low until the middle of the MCA (ca. 950-900 cal BP). This period, however, shows inconsistent records across the western Great Basin. At Walker, Pyramid, Winnemucca, and Owens lakes, lake levels fall. In the Carson Sink and Mono Lake, an initial period of low lake levels is followed by a rapid transgression occurring around 950-800 cal BP in Mono Lake and 950-660 cal BP in Carson Sink. Cook et al. (2010) highlight 875-829 cal BP as an exceptionally wet period during the MCA, especially in the upper Walker River watershed, explaining the high lake levels in both Carson Sink and Mono Lake. Interestingly, in the Carson Sink, this transgression event is quite extreme, resulting in one of its two highest-known lake levels during the last 5,000 years (Adams and Rhodes 2019b). Adams and Rhodes (2019b) suggest Walker River flow may have split, flowing both north to Carson Sink and south to Walker Lake during parts of the period from 1,500-700 cal BP. Such conditions could explain Walker Lake elevations between 1,212-1,205 masl until ~860 cal BP. Afterwards, there is an unexpected, pronounced drop in Walker Lake at ~860-800 cal BP during the MCA wet period, which occurs simultaneously to the dramatic lake level rise in the Carson Sink compared to other regional basins. Therefore, despite wetter climatic conditions, it is very likely the mid-MCA Walker Lake desiccation was due to diversion of the Walker River north through Adrian Gap to the Carson Sink. Perhaps the trigger for an avulsion event at this time was the rapid increase in wet conditions identified by Cook et al. (2010) following a dry period, which then resulted in enough downcutting to produce a north-flowing channel that effectively cut off water flow to Walker Lake and maximized flow into the Carson Sink.

Data presented here in tandem with known lake levels from other lake basins in the western Great Basin and other paleo-proxy records indicate that climate was the main driving force behind the late Holocene lake level history in the Walker Lake basin; however, river diversion during at least one fluctuation event cannot be ruled out. More specifically, during the early part of the late Holocene, 2,500-1,000 cal BP, the lake fluctuations from very low to near historic highstand levels seem to be in sync with other lake records from the surrounding region and with climatic signals across the Great Basin. The second sharp and extremely low-lake event witnessed at ~860-800 cal BP does not fit the general pattern of increased moisture across the region. This coupled with the contemporaneous and equally rapid rise of Carson Sink suggests the Walker River was diverted to Carson Sink and abandoned its pathway to the WLB. We suspect the trigger for such a river diversion at this time was ultimately the increased precipitation occurring around the region. Additional survey, testing, and sampling will help resolve questions about the mechanisms controlling lake levels in the WLB. For example, survey and testing closer to the lake margins may evidence alluvial fan materials at the lake margins. These landform types require mesic conditions to form, but their presence out in the basin near lake margins would indicate the lake was low and, itself, not responding to such climatic conditions, thereby providing further support for Walker River diversion to the Carson Sink. Additional radiocarbon dating will also provide a more robust dataset for understanding the timing of different depositional events across the Walker Basin.

3.4.4. Environmental and Landform Fluctuations in the Walker Lake Basin

The observations from cutbanks and organic materials recovered from the screens provide important information revealing the nature of landform stability across the lower WLB as well as new evidence for changes in ecological productivity. Beginning with landform stability, it appears that the rate and amount of lake-level transgression and recession in the lower basin is closely tied to elevation. The cutbank observations point to a variable number of coarse-to-fine sediment transitions that increase as elevation decreases. Further, the number of coarse-to-fine sediment transitions relative to cutbank thickness is greater in cutbanks 4-6 between 1,211.2-1,210.1 masl. This elevation range may be associated with more variable lake levels and/or fluvial conditions resulting in different depositional-energy regimes. Nonetheless, there is still evidence for a high number of coarse-to-fine-grained sediment transitions below 1,210.1 masl in cutbanks 7 and 8. It is not until 1,194.31 masl, the elevation of the auger, that there is evidence for more stable lake conditions.

Without clear temporal markers, it is difficult to chronologically correlate the number of transitions found across the cutbank record where differing rates of deposition or erosion may allow for varying amounts of sediment accumulation and/or preservation. Fortunately, the tephra deposit associated with the North Mono Eruption found in cutbanks 2, 3, 5, the upper cutbank 7 tephra, and the auger provide a valuable marker horizon. The tephra in cutbank 2 is associated with bedded sand, and as such, near the lake level at 650 cal BP. The lake appears to have been relatively stable around the cutbank 2 elevation (1,230 masl) prior to this event, as only fine-grained sediments are found below it. After tephra deposition, lake level receded and transgressed at least once across 1,230 masl. In cutbank 3, the tephra is in coarse and fine-grained materials, suggesting the lake was above this elevation (1,221.5 masl) but in decline during the eruption. After the tephra was deposited, the lake receded and transgressed twice across 1,221.5 masl. The interpretation that the tephra was deposited during lake-level decline just after transgression is further evinced by the tephra-bearing clays capping organic and charcoal-rich sands in cutbank 5. These clays appear to have been eroded by a post-tephra recession, mixing medium sands with the tephra material. There appear to have been three lake recessions and transgressions across the elevations above the cutbank 5 tephra, 1,208.7-1,210.1 masl, after it was deposited. In cutbank 7 the North Mono Tephra is deposited in a much thicker clay and silt deposit, but like cutbank 5 it is directly capped by medium sands. This is the only coarse-grained deposit above the tephra in this cutbank, suggesting that the lake only fell below this cutbank at 1208 masl once between tephra deposition and the modern recession. Finally, the tephras in the auger and all of the excavation blocks are only capped by fine-grained deep-water deposits, indicating that the lake recessions post-dating the tephra did not reach the auger elevation at 1,194 masl until ~2014, and that they have never fallen below the 2014 lowstand since the North Mono Eruption.

The transgression and recession observations relative to the North Mono Tepha in cutbanks across the lower WLB follow a pattern of increased lake elevation instability as elevation decreases, with especially high instability between 1,211.2-1,210.1 masl. The instability of lake levels here is largely due to the shape of the WLB just below this elevation range. This portion of the basin is associated with Pelican Point to the west and an alluvial fan bulge to the east (Figure 3.5). These landforms narrow the valley floor, creating a choke point across which water would rise and fall more quickly relative to areas to the north and south. As a result, changes to lake elevation above and below this choke point would have required greater lake volume shifts. During wet periods when Walker River flowed into the WLB, variable snowpack or precipitation would have minimally altered lake levels associated with Holocene highstands between 1250-1260 masl (Adams and Rhodes 2019b). Conversely, during extreme drought or river avulsion into the Carson Sink, only extreme amounts of precipitation or river flow back into the WLB would have allowed the lake to climb above lowstand elevations at 1180-1200 masl. However, if the lake were within ~10 m of 1210 masl, perhaps during moderate drought or river flow split between the WLB and Carson Sink, it is possible that minor climate fluctuations would allow the lake to rise and fall above the choke point, creating a more complex record of lake-level change in this area.

In addition to changes in lake-level fluctuations across landforms within the WLB, organic materials collected during excavations reveal the relative environmental productivity within the basin during the last millennium. The materials recovered above the North Mono tephra show that the upper levels consistently contain abundant floral material and few fish remains. This likely reflects the fact that these sediments were recently deposited when fish populations were in severe decline or non-existent and that they contain abundant floral materials that have yet to decay. A peak in faunal bone numbers in levels 5-7 is associated with relatively stable or declining floral material. This may mark the beginning of artificial fish stocking in Walker Lake during the historic lake recession. Above these fish-bone peaks, the presence of faunal remains consistently declines with higher elevation. At the same time, there appears to be little evidence for fluctuations in the local plant community. Faunal counts are reduced below levels 5-7 in all the blocks, marking a decline in fish productivity. In TB-1, bone counts begin to increase with level 10, showing spikes in levels 14 and 17. Level 17 is also associated with a small uptick in the otherwise stable floral counts. This may point to a relatively wet period in the WLB. Level 9 in TB-2 and level 10 in TB-3 are associated with increases in fish bone, though this change is much greater in TB-3. Floral material remains relatively stable or slightly decreases in these levels. Based on the level depths relative to the tephras, the level 17, 9, and 10 fauna increases in TB-1, 2, and 3 respectively may mark the historic highstand after the lowstand at 300 cal BP when lake productivity last peaked. Below level 17, TB-1 fish counts fall again; however, they have an upward trend from levels 20-17, implying increasing fish populations associated with rising lake levels (Finney et al. 2010; O'Connell and Tunnicliffe 2001). The same pattern of increasing fauna counts occurs in TB-3 from levels 14-10. In TB-2, the opposite pattern occurs from levels 15-9, but the changes in bone counts are less pronounced.

In both TB-2 and TB-3, the levels surrounding the tephra show large spikes in fish bone and floral counts. This is surprising because the tephra was deposited during a period of lake recession (Figures 3.15 and 3.16). During a recession, fish populations should drop (Beutel et al 2001) and reduced water availability should correspond to fewer plants. These spikes may instead be the result of tephra deposition. The volcanic ash deposited in the lake and surrounding area may have resulted in the death of large numbers fish as water chemistry was affected. Local plants may have also been impacted by cooler weather or other deleterious effects. As a result, a short-term spike in both fish and plant remains would have occurred just after tephra deposition as dead organic matter. The signal in the data across multiple levels is likely the result of a sloping tephra surface in the excavation blocks, allowing multiple levels to show the effects the tephra had on the environment. There are only two or three levels below the tephra in TB-2 and TB-3, so a clear pattern of pre-tephra organic productivity is not present, especially because the patterns for organic material counts in these levels are inconsistent. In TB-2 the amount of organic material increases from level 20-18, suggesting increasing productivity. Conversely, in TB-3 bone counts decrease from levels 21-18b while floral counts are roughly constant. Deeper excavation and sampling in these areas would help reveal the pre-tephra productivity in the lake.

3.5. Conclusions

Adams (2007:138) argued that by completing in-depth research combining various proxy records, a more detailed record of lake-level history could be established.

Adams and Rhodes (2019b) do this by providing new shoreline IRSL dates, modeling lake levels using estimated water flow, and studying fluvial stratigraphy in the Adrian Gap. This study continues this research by combining numerous records to expand our understanding of the history of Walker Lake during the late Holocene.

The investigations below the waterline illustrate important areas of research for building upon our understanding of landform preservation, lake chronology, and environmental change. While past research investigated materials below the lake in the form of cores and acoustic mapping (Benson 1988), issues with this early work minimized its impact for understanding submerged sediments and submerged and buried landform features. Since these early efforts, work within the lake has been minimal. This paper describes data recovered using newer sub-bottom technology to provide clearer imagery of the submerged sediments and combines these efforts with targeted excavation and coring to establish the presence of invaluable submerged data in the lake and better define its history.

This refined lake history is the result of using both underwater investigations and the terrestrial cutbank record. W studied the depositional record of submerged sediments to establish a radiocarbon chronology and developed a model for the depositional events recorded. The cutbanks detailed allowed for a comparison of lake fluctuations at higher elevations. This permitted stratigraphic and geochemical comparisons of tephra deposits below and above the waterline. As a result, I identified the North and South Mono Tephra marker horizons which help to further refine the lake-level curve. This refined curve establishes a lake lowstand in shoreline sands at 1,178 masl dating to 2,200 cal

BP, marks a lake recession across ~1,208 masl during the South Mono Eruption at 1,325 cal BP, identifies another lowstand at 1180 masl dating to ~800 cal BP, and notes that the lake receded across ~1,235 masl during the North Mono Eruption at 650 cal BP.

These results broaden the existing data for lake level changes in the region, and when the results for the WLB are compared to other nearby lakes, it appears that both environment and river direction played an impact, with recessions dating to 2500-2000 and 1,500-860 cal BP largely being controlled by local climate conditions. From 860-800 cal BP the extreme lowstand may have been caused by river avulsion resulting from a wet period dating from 875-829 cal BP.

The cutbank data point to a series of lake fluctuations before and after the North Mono Eruption, especially around Pelican Point. Contextual and temporal correlations between cutbank stratigraphy and excavation blocks were possible using the North Mono Tephra. These comparisons show that lake-level stability decreases with elevation below 1,232.47 masl before becoming more stable by 1,194.31 masl. Between 1210-1212 masl, lake levels may have been especially unstable due to the shape of the basin. Test excavations revealed interesting correlations between the presence of woody terrestrial material and fish remains suggesting that water flow allowed for the deposition of increased woody material during higher lake levels corresponding to higher fish populations. The North Mono Eruptions may have resulted in a mass die-off of both fauna and flora, resulting in exceptionally high organic deposits above and below the associated tephra layer.

Taken together, these data provide important environmental information to assist with investigations into human use of the WLB. Identifying periods of low lake level allows archaeologists to target preserved terrestrial features within Walker Lake and test for buried sites underneath the lake that may contain unique records of organic materials or foodways. Understanding the broader patterns of environmental and river productivity allow for models predicting when and how populations may have used the region. Alternatively, if populations are known to have been in the basin during a given time, information about the basin's water and environmental conditions can help archaeologists build models connecting sites and archaeological materials to broader frameworks related to behavioral ecology and technological adaptations.

Beyond archaeology, the results of this study demonstrate productive avenues for further research. One of the most useful areas for additional work is further sub-bottom survey across the northern half of the lake. Fully covering this area with narrow survey transects will reveal the extent of preserved features within the lake. The use of improved methodologies and newer technology would also be fruitful. Survey equipment using modern CHIRP systems (e.g., Edgetech 3400) or a parametric sub-bottom (e.g., Innomar SES-2000) would improve profile resolution and further reveal intact features. These data would allow us to fully map fluvial and lacustrine features within the lake and improve the resolution of deeply buried deposits. An extensive underwater testing and coring program targeting preserved fluvial and lacustrine landforms would also provide information about historic lake ecology, the mechanisms that resulted in lake rise and fall, and the extent of past lake desiccation events.

Additional radiocarbon testing from cutbanks will further narrow and improve the date ranges for transgressions and recessions while providing better correlations between them. In addition to the methods discussed here, future studies should consider using methods already successfully applied to the region (e.g., $\delta^{18}O$ studies, diatom analyses, and palynology).

Understanding the history of Walker Lake is invaluable for improving lake health and for ongoing efforts to preserve and restore the lake to its historic condition. Understanding lake-level and ecological history will also clarify how climate or other environmental factors have impacted the lake. These studies will also support research into the history of humans in the Walker Lake basin and allow archaeologists to identify buried, preserved sites in the lake, revealing unprecedented information about past populations and cultures (e.g., Chatters et al. 2014; Faught 2004; Halligan et al. 2016; O'Shea and Meadows 2008). Together, this work will continue to allow for successful ecological, cultural, and climatic management of the Walker Lake Basin.

4. A STATISTICAL INVESTIGATION OF LANDSCAPE ADAPTATIONS ACROSS THE WALKER LAKE BASIN, NEVADA

4.1. Introduction

Investigations into landscape use and technological adaptations are central to archaeological research grounded in human behavioral ecology (Adams et al. 2008; Binford 1979, 1982, 1991; Estes 2009; Robinson and Sellet 2018). This research acknowledges the relationship between human activities and the environment as it pertains to populations successfully exploiting available resources. These behaviors are tied to the technology people use to acquire, process, and consume resources. How technology is used across a landscape and through time helps to reveal past populations' economic and social organization (Binford 1979, 2001; Custer and Wallace 1982; Kuhn 1995; Smith and Harvey 2018; Wallis 2008). In addition to the nature of tools across the landscape, the organization of populations at different times and across different landforms can further reveal human social, technological, and economic structures (Coughlan and Nelson 2019; Jones et al. 2003; Smith 2011; Smith et al. 2013a). In the Great Basin, these relationships have been intensely investigated, resulting in the development of various models for human behavior across the region, especially as humans adapted to changes in climate (Graf and Schmidt 2007, Grayson 2011, Madsen et al. 2015). This paper investigates how artifact distributions in the Walker Lake basin reveal disparate technological and provisioning patterns indicative of settlement organization relative to specific landform types and elevation ranges. The study also highlights how Walker Lake basin landscape use and behavioral adaptations change over time. The first part of the paper presents landscape use models in the Great Basin, archaeological research from nearby sub-basins, and models relating technological provisioning and mobility. Following this is a discussion of the Walker Lake basin and the dataset used to test the relationship between landscape and technological provisioning, and a summary of the statistical approaches adopted. Results show patterns of variable landscape use over time and a strong relationship between landforms and behavioral adaptations based on the distribution of artifact counts and their variety across the Walker Lake basin.

4.1.1. Landscape Use in the Great Basin

Models of landscape use and adaptations in the Great Basin are often temporally focused, working towards explaining how populations at different times exploited and adapted to the region's environmental and climatic shifts. Populations identified as Paleoindian are consistently classified as highly mobile foragers with specialized toolkits, including lanceolate or stemmed projectile points, large bifaces, scrapers, and high-quality toolstone (Anderson and Sassaman 1996; Beck and Jones 2011; Beck et al. 2002; Bever 2001; Goebel 2007; Goodyear 1989; Graf 2001; Hoffecker et al. 1993; Jones et al. 2003; Meltzer 1988; Shott 1993, Smith 2007, 2010). While across much of North America Paleoindians are associated with large-game hunting, in the Great Basin these populations are often correlated to a subsistence strategy focused on smaller game, some plant use, and open-air locations on pluvial-lake and marsh landforms (Adams et al. 2008; Bedwell 1973; Campbell et al. 1937; Cummings 2004; Duke and Young 2007; Goebel et al. 2011; Grayson 2011; Hockett 2007; Jones et al. 2003; Rhode and Louderback 2007; Smith et al. 2020; Thomas et al. 1983). These observations give rise to conflicting models of late Pleistocene foraging and land use. The tethered-wetland model suggests early populations focused primarily on marsh and lacustrine resources (Bedwell 1973; Jones and Beck 1999). Conversely, the mobile-forager model argues late Pleistocene people were not restricted by wetland resources. Instead, they had a broad diet breadth and were highly mobile, procuring resources far from marshes (Beck and Jones 2011; Jones and Beck 1999; Simms 1988). Evidence used to investigate these models is wide ranging, but typically has focused on studies of foodways and technological provisioning at rockshelter sites where perishable materials are well-preserved (Cummings 2004; Eiselt 1997; Goebel 2007; Grayson 2011; Rhode and Louderback 2007; Hockett 2007, 2015, 2017).

Similar models for landscape use have been developed for the Holocene. The limnosedentism model argues that populations in the Great Basin reduced their mobility when exploiting lacustrine and marsh resources (Heizer 1967; Thomas 1985). The proximity between these resources and their associated landscapes supports this position, as does the relatively homogeneous floral and faunal materials at sites associated with lakes and marshes. Conversely, limnomobility acknowledges that, while people occupying sites at lakes and marshes use lacustrine and wetland resources, the absence of materials and resources from non-marsh/lacustrine environments does not prove such resources went unexploited. Instead, the use of low-ranked resources at lakes and marshes would have required regular movement between these and other environments, encouraging use of upland resources during movement between patches (e.g., to procure piñon nuts and mountain sheep) (Thomas 1985).

During the late Holocene, Bettinger and Baumhoff (1982) argued that the movement of Numic speaking populations into the Great Basin gave rise to the traveler/processor dichotomy, in which pre-Numic "travelers" were out-competed and replaced by Numic groups that more intensively exploited a broad range of available resources. Under this model, travelers regularly moved between resource patches, relying on a wide range of environments in which high-ranked resources were moderately exploited. Processors, however, were able to take advantage of both high and low-ranked resources for longer periods, reducing their mobility and increasing their population density (Bettinger 1994; Bettinger and Baumhoff 1982, 1983; Young and Bettinger 1992). This model is contested on various grounds, including the absence of evidence for differential landscape exploitation, questions of adequate resource use by processors, and uncertainty of population replacement (Broughton and Grayson 1993; Grayson 1991; Simms 1983a; Thomas 1994, 2014b). Nonetheless, the Bettinger model still holds important interpretive value for explaining the emergence of the intensive foraging strategies documented in archaeological and ethnographic records in the Great Basin.

The common theme among these models is the relative mobility of populations exploiting various landforms. Hypotheses for reduced mobility generally argue for increased lacustrine and marsh resource use at the expense of upland resource

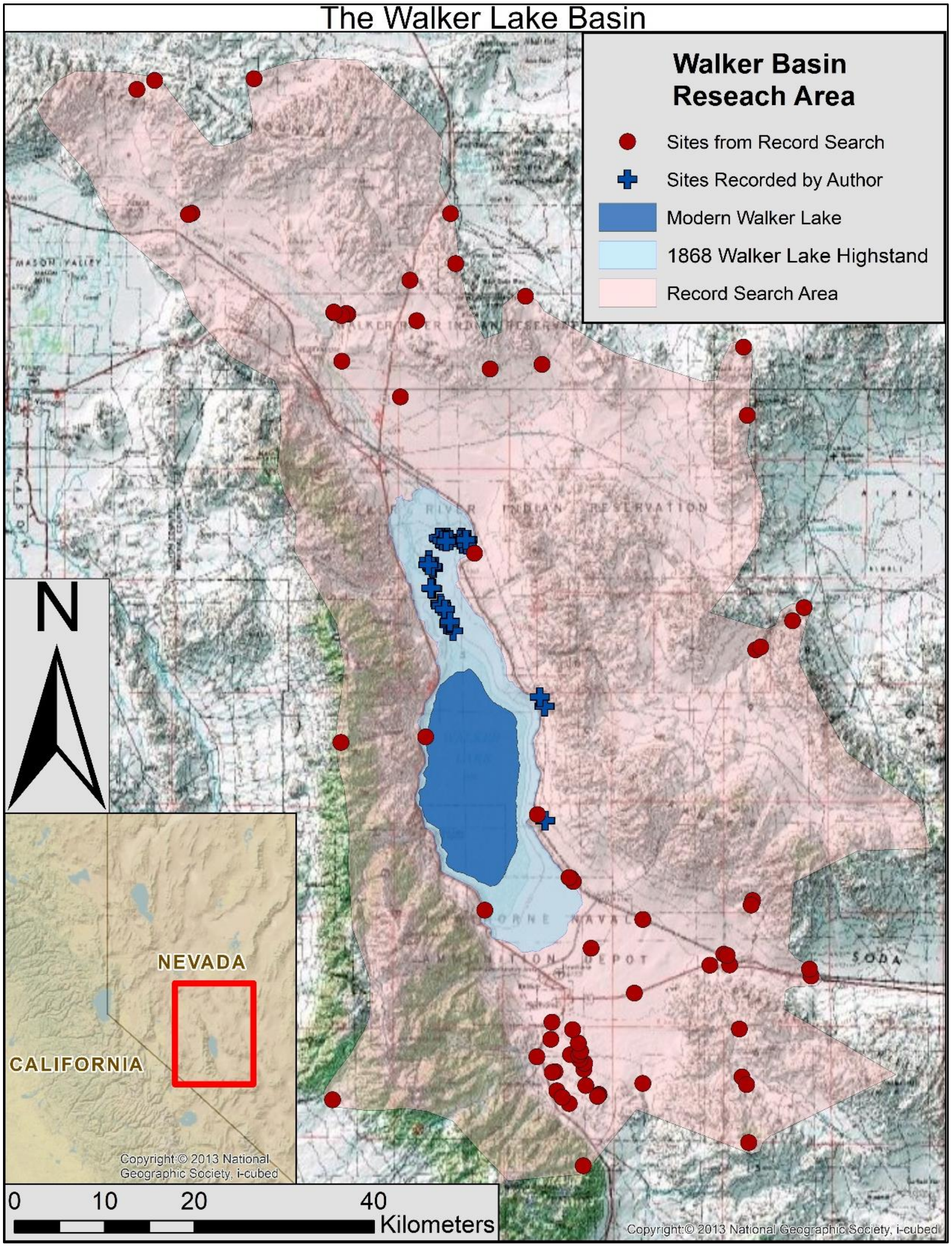

Figure 4.1. Walker Lake basin research area showing record search area, modern lake level, historic lake level, and sites discussed in this paper. Topographic basemap (National Geographic Society 2013) and inset map (ESRI 2017) modified by author in ArcMap 10.6.

exploitation. While no models argue lowland-water resources were used exclusively, the contention that lakes and marshes contributed to reduced mobility suggests resource use outside these environments required specialized behavioral approaches and technological adaptations. Contrary models centered on higher residential mobility argue lacustrine and marsh resources were consistent parts of a wider resource-use strategy and thus adaptive and technological approaches across the landscape should have been less specialized.

This paper investigates the relationship between Great Basin landscapes and technological adaptations in western Nevada's Walker Lake basin (Figure 4.1) using a statistical approach. I compare several lithic-technological and spatial variables to determine the presence and patterning of toolkit distributions associated with site ages, lacustrine and fluvial landforms, and elevation ranges. The results are valuable for comparing landscape use within the Walker Lake basin to broad models of Great Basin landscape exploitation and mobility.

4.1.2. The Regional Archaeological Record

North of the Walker Lake basin, the Carson Desert contains numerous wetlands including the Carson Sink, Stillwater marsh, and Carson Lake (the southern sub-basins of the Lake Lahontan system). Archaeological research and landscape-use modeling in the southern Lahontan basin are generally indicative of increased landscape exploitation through time. During the late Pleistocene and early Holocene, when the earliest human occupations occurred, much of the Carson Desert was underwater, limiting regional use to the shores of the existing lake and higher (Adams et al. 2008). While there is clear evidence for Paleoindian occupations at this time, these appear to have been limited to surface contexts on ancient shoreline features such as the Sadmat site (Adams et al. 2008; Graf 2001). These sites are associated with the well documented pattern of highly mobile populations occupying pluvial lake shorelines while moving across broad conveyance zones in the western Great Basin (Graf 2001; Smith 2010). Besides the surface record, an important component of the early Holocene record of southern Lahontan basin is the human remains from Sprit cave dating to 10,500 cal BP (Hockett and Palus 2018; Wheeler and Wheeler 1969), which provide evidence of a broad diet including a variety of marsh resources as well as sophisticated perishable technology (Eiselt 1997; Jantz and Owsley 1997; Napton 1997; Tuohy and Dansie 1997). Near the Carson Desert, however, there is little evidence for broader land use in the uplands or away from shorelines before the middle Holocene. This includes an absence of sites from the Stillwater mountains or other uplands before ~5,000 calendar years before present (cal BP) (Kelly 2001, 2011).

Early archaeological research focused on the record from the middle Holocene and later, addressed the Desert Culture model proposed by Steward (Jennings 1957; Steward 1938). This model suggested that Great Basin populations had been effectively homogenous for 9000 years, that people were highly mobile, and that they were focused almost entirely on resource acquisition as they continuously moved between resource patches foraging for whatever food was available (Jennings 1957). Later, excavations by Heizer and colleagues at Humboldt Cave, Lovelock Cave, the caves around Grimes

Point and other sites revealed an extensive record of cached perishable materials, seasonal cave and rockshelter use during the late fall through early spring (Napton and Heizer 1970). These caves appear to have been primarily used after 5,000 cal BP with their most intensive use between 3,500-1,250 cal BP. The overwhelming dominance of cultural materials associated with wetland resource suggested an overall emphasis on lake and marsh landscape exploitation in and around the Carson Desert region. Heizer used these data to argue for a more sedentary pattern of resource use focused on wetland resources (Heizer 1951, 1956, 1967; Heizer and Baumhoff 1958; Heizer and Krieger 1956; Heizer and Napton 1970; Kelly 2001; Napton and Heizer 1970; Thomas 1985). Thomas (1985) returned to Hidden Cave in 1980-81, where excavations again revealed abundant wetland-associated materials but little evidence for residential cave use. Instead, the cave record was interpreted as a storage location for personal gear, with some use as a burial site, resource cache location, and resting spot people would have visited to escape the more extreme conditions found in the Carson Desert (Thomas 1985). Thomas argued Hidden Cave showed evidence for a mobile residential strategy in which people only ephemerally using caves and rockshelters while moving between resource patches.

Kelly's work supports Thomas' interpretation, showing evidence for increasingly intensive landscape use and reduced mobility across the region over time (Kelly **1985**, 2001). He conducted broad survey across the Carson Desert and Stillwater mountains and then used lithic analysis and optimal-foraging models to consider changing mobility and landscape use through time. In addition to Kelly's work, high water levels and flooding during the mid-1980s resulted in the exposure of many previously unknown sites and burials across the Carson Desert. The resulting archaeological research helped to clarify residential patterns and was used to model gendered activities tied to expectations from an optimal-foraging model (Raven and Elston 1989; Raven 1990; Zeanah et al. 1995**)**. The results indicated that prior to 2,000 cal BP populations were mobile within the Carson Desert, using the marshland as hubs and moving in and out of the region with the expectation of returning to the wetlands. After 2,000 cal BP, there is evidence for reduced mobility and perhaps multi-season marsh occupations. The Stillwater Mountains appear to have been logistically used at this time but not residentially occupied. After 650 cal BP, the record is less definitive. The residential occupations of Stillwater Marsh appear to have been shorter, indicating higher overall residential mobility with more frequent moves out of the wetlands. Conversely, this may be a sampling issue (Kelly 2001:123), as populations may have just moved short distances to other marsh locations where longer occupations occured. Kelly (2001) argues that these trends generally follow the expectations for marsh productivity based on climate change. Zeanah (2004) suggests that the overall mobility strategy was due to the importance of woman's foraging to providing necessary calories, which then controlled patch choice locations and required men to hunt logistically. In either case, the overall productivity of marsh and wetland resources appear to have controlled mobility and subsistence strategies in the Carson Desert after 5000 cal BP.

South of the Walker Lake basin, the Mono Lake basin is an environment similar to Walker Lake, with steep sides, large changes in lake elevation, and less marsh habitat than is available in the Carson Desert (Brady 2009; Stine 1990). Brady (2009, 2011) conducted systematic archaeological survey across randomly sampled locations in three different wetland ecosystems (freshwater, brackish, and saline). In addition to recording all identified archaeological materials, hydration rinds and source locations were identified for all obsidian artifacts. The results indicate that during the late Pleistocene and early to middle Holocene, human occupation in the region focused on the brackish wetlands where there is evidence for increased mobility and individual provisioning in the form of high obsidian-source diversity and an emphasis on curated tools such as bifaces. After 6,000 cal BP, land use was more focused on saline wetlands, while people increased their exploitation of local obsidian sources. Nonetheless obsidian source diversity continued to be high. This may suggest local landscape learning and high residential mobility. Beginning around 3,200 cal BP, local populations adopted a broad wetland use strategy, showing no clear preference for any given area. However, there was no shift in toolstone choice, suggesting increasing landscape exploitation but not changing mobility patterns. Around 1,500 cal BP, landscape use returned to brackish wetlands and the use of local obsidian material dropped, suggesting reduced local landscape exploitation and increased residential mobility. During the late Holocene after 1,350 cal BP, toolstone diversity dropped to its lowest level, becoming almost completely limited to local material. At the same time, local occupations shifted to the fresh-water wetlands where there is evidence of increased sedentism. Overall, the Mono Basin shows decreasing mobility over time along with increasing local landscape exploitation, with one noticeable reversal occurring between 1,500-1,350 cal BP (Brady 2011).

South of Mono Lake, Owens Valley has been subject to extensive research since the 1930s, producing an exceptional ethnographic and archaeological record (Bettinger 1977, 1979; Eerkens 2003, 2012; Eerkens et al. 2008). Evidence from sites dating to the early Holocene suggest residentially mobile foragers primarily using Owens Lake for fish and waterfowl (Bettinger 1999). Early sites, while showing focused exploitation of lacustrine resources, nevertheless are distributed across wider contexts indicating broad resource exploitation across a residential range of 150 km or more (Basgall 1989; Delacorte 1999). During the middle to early-late Holocene, 7,000-3,500 cal BP, there are relatively few sites in Owens Valley and most of these consist of surface scatters (Eerkens et al. 2007). The overall signature of sites from this period is reminiscent of the early Holocene. Researchers note, however, an overall increase in the use of ground stone during this period, inferring increased resource exploitation and possibly longer residential occupations (Eerkens 2012). During the late Holocene populations appear to have become less mobile and more logistically organized. By 3,500 cal BP larger residential structures were constructed and there is evidence of reduced mobility in the form of more restricted, shorter obsidian conveyance zones focused on particular sources (Eerkens et al. 2008). At 1,500 cal BP, population levels appear to have increased alongside expanded use of small mammals such as lagomorphs. The distance associated with logistical forays appears to decrease, with only the most locally available toolstone material exploited. People also began to construct large semi-subterranean structures suggesting a more sedentary pattern of mobility (Eerkens 2003, 2012; Eerkens and Spurling 2008). It is also at this time that villages are established in the high elevations of the White Mountains above 3100 masl. These villages show intensive use of seed and plant resources as opposed to the earlier, artiodactyl focused hunting sites (Bettinger 1991; Grayson 1991). After 700 cal BP, the post-1,500 cal BP pattern continued, but with higher populations densities and increased landscape exploitation (e.g., higher seed processing, large amounts of ground stone, pottery use, and the exploitation of freshwater mussels) (Bettinger 1977; Bettinger and Baumhoff 1982). Logistical forays expanded to include more distant obsidian resources and exotic goods entered the archaeological record, indicative of broader trade networks. At the same time, household sizes decreased, perhaps becoming more focused on the nuclear family (Eerkens 2003, 2004; Santy and Eerkens 2010). Like with the Carson Desert, the Owens Valley record can in some ways be correlated to the environmental record. Rising lake levels from ~4,000-3,000 cal BP point to more productive environments while the shrinking household sizes between 1,200-700 cal BP closely correlates to the Medieval Climatic Anomaly, a period of drought and low lake levels in the Owens Valley (Bacon et al. 2006). The broader pattern, however, suggests a wider range of causes driving cultural and behavioral changes including population density, extended social networks, and new technologies (Bettinger and Baumhoff 1982; Eerkens 2004, 2012).

In addition to the changes in landscape use, technological organization, and mobility patterns across the Carson Desert, Mono Lake, and Owens Valley, regional models have been developed to better understand unique cultural changes in the western

Great Basin. McGuire and Hildebrandt (2005) proposed the adoption of prestige hunting as a form of costly signaling between 4,500-1,000 cal BP. They suggest that hunters worked to obtain large game to improve their chances of optimal mate selection, thus increasing their reproductive success. This, they argue, was a response to earlier periods of drought, and while not economical or efficient, may have been an important cultural activity. Another model concerns the construction of large-scale, communal hunting features across the northeastern, central, and western Great Basin. These features were constructed beginning ~5,000 cal BP, and their densest concentration occurs in the western Great Basin just west and south of Walker Lake (Hockett et al. 2013). The range of communal hunting features includes corrals, fences, and corral-fences, and based on analysis by Hockett et al. (2013), would have required groups of 20-60 people to construct in a timely and effective manner. These resulting structures would have supported large communal gatherings, allowing multiple families to comingle, which would have helped build alliances, allowed for match-making, and supported conflict-avoidance strategies across the Great Basin.

The overall trend across the southern Lake Lahontan sub-basins, Mono Basin, and Owens Valley is one of decreasing mobility strategies and increasing, localized resource exploitation. After the middle Holocene warming period, new strategies focused on communal hunting and prestige hunting seem to have also appeared (Hockett et al. 2013; McGuire and Hildebrandt 2005), providing both intergroup cooperation opportunities and chances for male hunters to demonstrate their value to potential partners. These patterns provide essential context for interpreting the Walker Lake basin archaeological record and its relationship to the broader region. As such, the results of the analyses in this paper provide a broader understanding of the archaeological record as the observed patterns of mobility, landscape use, and subsistence strategies are placed in regional context. This allows researchers to compare and interpret the relationships between humans and landscapes across neighboring sub-basins, ultimately leading to more robust and inclusive models of landscape use and behavioral adaptations.

4.1.3. Lithic Technological Organization and Provisioning Strategies

The relationship between toolstone, subsistence, and mobility has been investigated for more than four decades. Standardized models place foraging groups along a continuum between residentially-organized/highly-mobile populations and logistically-organized/less-mobile populations (Binford 1980, 1991, 2001; Graf 2010; Kelly 1995; Kuhn 1995). Residentially-organized populations focus on provisioning individual hunter-gatherers by equipping them with a small number of lightweight, effective tools made on quality material, in part because these populations acquire lithic raw materials (or toolstone) when they are encountered. In this case, a provisioning-individuals strategy reduces the risk of unexpected shortfalls in resource supply when an entire group is highly mobile. Archaeologically, I expect these toolkits to contain tools that are well-made, formal, durable, and can be used for multiple tasks. I also expect higher rates of tool sharpening and reuse as well as longer distances traveled between raw material (or toolstone) sources. In contrast, logistically-organized populations are associated with overall-reduced mobility and provisioning-place activities. They supply residential locations with an abundance of locally-available toolstone to make a wide range of tools, some formal and durable, but many more informal and expedient. They either move lithic raw materials to their bases or locate their residential bases at or very near quality lithic resources. Populations provisioning place use small logistical groups to travel long distances in search of toolstone or other resources not available at the provisioned location. Therefore, within a provisioning-place strategy, only individuals in logistical groups will need to be provisioned (Graf 2010, Kelly 1988; Kuhn 1995; Odell 1996; Smith et al. 2013b).

In the Great Basin, most studies of technological organization focus on Paleoindian populations, showing that these groups were generally residentially organized, highly mobile, focused on high-quality toolstone, and provisioned individuals (Duke and Young 2007; Estes 2009; Graf 2001; Jones et al. 2003; Knell 2014; Newlander 2012; Smith 2007; Smith et al. 2013b). Later, foragers increased their use of local materials to make and use more expedient tools while increasingly exploiting local resources, a pattern well-documented at Monitor Valley and Gatecliff Shelter (Thomas 1983; Thomas et al. 1983, 1988). In the Carson Valley Kelly (1985, 2001) and Raven and Elston (1988) discussed the nature of site assemblages, tools, and toolstone to approximate relative mobility during the late Holocene, generally arguing for reduced mobility from the Middle to Late Archaic (3,500-600 cal BP).

From a landscape-use perspective, consistent and focused exploitation of lacustrine and marsh resources and reduced mobility over time should result in more logistically-organized populations based in lacustrine and marsh environments. These groups are likely to use a wider range of tools at the base camp, exploit mostly local toolstone, and occupy lacustrine and marsh residences for longer periods. In contrast, their sites away from marshes and lakes should express less diversity in type and a higher number of more formal, curated, and specialized tools, such as bifaces and points, designed for specific tasks performed at logistical locations. In this case, I expect to find a pattern of high between-site variability, with high within-site variability only at lacustrine-based, residential sites, and low within-site variability at all other, logistical, sites in the system. If populations were residentially organized, there should be little difference between lithic artifacts at given sites across the landscape (i.e., low between-site artifact variability). Because most sites in this land-use strategy should be base camps, there should be numerous tool types representing varied tasks performed at residential bases (i.e., high within-site artifact variability). To best understand the relationship between technological organization and landscape, correlating sites with their temporal range helps to show how populations adapted mobility strategies and landscape use relative to landscape changes through time; however, the Great Basin has an abundance of undated, mostly surface, lithic scatters that can be used to model general landscape use, but that lack good chronological control. The Walker Lake basin is no exception. Therefore, while in this paper I consider the question of change over time based on the presence of temporally-diagnostic artifact types, I primarily concentrate on surface-artifact distributions to investigate spatial patterning for a general understanding of Walker Basin landscape use.

4.1.4. Research Questions and Hypotheses

This paper relates the Walker Lake basin archaeological record to models for landscape use, mobility, and technological organization by focusing on three general questions. First, how does the record compare to general Great Basin models for landscape use relative to wetlands and late Holocene population changes? Second, does the Walker Basin record conform to the patterns of landscape use found in nearby regions such the Carson Desert, Mono Lake basin, and nearby uplands? Third, how does the archaeological record relate to existing models for lake and environmental changes in the Walker Lake basin? To answer these questions, this paper focuses on landscape use over space and time to compare technological organization, mobility, and subsistence strategies. Using a series of statistical tests, I compare site distribution, lithic technology, and age to both site elevation and water-related landforms. These tests investigate whether the lithic technologies associated with sites at the lower, middle, and upper elevations, as well as sites associated with washes, the Walker River, and Walker Lake, show statistically significant differences in tool technology. I also compare sites containing typologically-dated artifacts with elevation and landforms to look for statistically significant differences in landscape use at different times. These analyses test the following statistical null hypothesis:

H_0: If populations associated with specific time periods did not exploit different landscapes (H_1), or past populations expressed no clear differences in technological organization relative to landscape use (H_2), then no significant differences will be observed between age distributions (H_{0-1}) or lithic artifact distributions (H_{0-2}) on the landscape.

If the results demonstrate significant differences in artifact and site distributions, then the null hypothesis may be rejected in support of the following alternative hypotheses:

H_1: If past populations demonstrated different preferences for landscape use and exploitation at different times, then the distribution of sites and artifacts dating to different periods will be significantly different relative to different landforms and elevations.

H_2: If populations organized their mobility, behavioral adaptations, and associated technological organization according to space, then lithic technological signatures represented by tool distributions and counts will demonstrate significant differences relative to landscape categories (i.e., elevation range and landform type).

While general, the null and alternative hypotheses have important implications for answering questions about the record in the Walker Lake basin. If supported, the null hypothesis would indicate a generally homogeneous record of landscape use, technological organization, and mobility through time. Conversely, if H_0 is rejected, the alternative hypotheses indicate changing adaptations across space and time in the Walker

Lake basin. In this case, the patterns observed in the statistical tests will reveal relative differences in landscape use, technology, and mobility. In either case, the patterns reflecting adaptive similarities or differences can be compared to models for mobility and social organization, records from nearby sub-basins, models for Great Basin landscape use, and reconstructions of the Walker Lake basin environment. These comparisons will reveal how the Walker Basin fits into the Great Basin record, broadening our understanding of the relationship between human adaptive behaviors and the environment.

4.2. Materials

4.2.1. The Walker Lake Basin's Archaeological Record

Walker Lake is a large, natural pluvial lake located in western Nevada at the edge of the Great Basin (Figure 4.1). It is bordered by the Gillis Range to the east, the Terrill Mountains to the north, and the Wassuk Range to the west and south. The watershed is ~10,500 km^2 and the lake is primarily fed by the Walker River flowing into the north end of the lake. Due to modern water diversion for agriculture, the river often goes dry before water reaches the lake (Adams 2007; Beutel et al. 2001). The lake has a current area of ~12,140 hectares with a maximum depth of ~24.4 m (BLM 2019; NDOW 2012).

Both the lake and the river have been subject to a complex series of changes over the last ~16,000 years. At 15,700 cal BP, the lake connected to pluvial lake Lahontan through Adrian Gap and reached its late Pleistocene Sehoo highstand at 1,338 meters above sea level (masl). Immediately after the highstand was reached, lake level rapidly fell, and the Walker River likely drained through Adrian Gap, into the Carson Desert (Adams 2007; Adams and Rhodes 2019b; Adams and Wesnousky 1998). As a result, lake levels remained low, potentially existing as a shallow marsh or dry playa until ~5,500 cal BP (Adams and Rhodes 2019b; Adams and Wesnousky 1998, Benson 1988; Benson and Thompson 1987; Bradbury et al. 1989). After 5,500 cal BP, a complex series of lake-level changes occurred within the basin, primarily driven by Walker River avulsion between the Walker Lake basin and Carson Sink, though climatic factors may have also had some impact (Figure 4.2) (Adams 2007; Adams and Rhodes 2019b; Puckett 2020, 2021). The 1868 historic highstand at 1,252 masl was followed by severe lake regression to a March 2020 level of 1,194.7 masl (Adams and Rhodes 2019b; Lakes Online 2020; Lopes and Smith 2007).

The present analysis incorporates previously recorded precontact sites in the lower Walker Lake basin as well as newly recorded sites from surveys in 2014-2016. Together, the two databases provide evidence from a total of 138 sites. Of these, 110 are used in this study, including 38 recorded in 2014-2016 and 72 recorded previously. Below I detail the methods for determining which sites were included in this research.

4.3. Methods

4.3.1. Data Collection

Fieldwork during 2014-2016 was completed using 30-m-transect surface surveys along major lacustrine and fluvial landforms north and east of Walker Lake. North of the

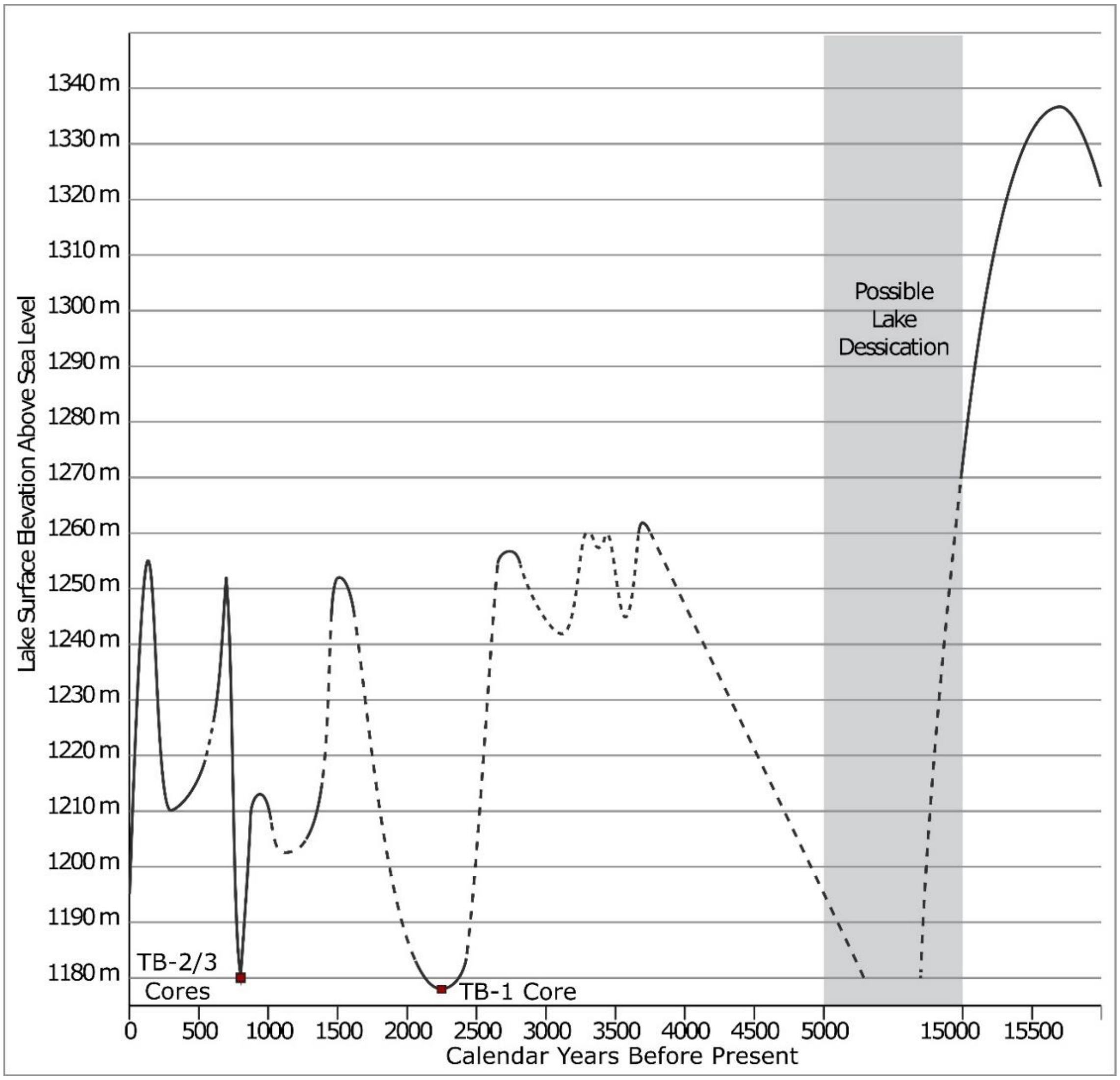

Figure 4.2. Walker Lake level curve for the last ~16,000 years. Solid lines represent established elevations, and dashed lines represent expected lake elevations based on the known curve. Red points on the curve represent inferred low lake levels, identified and reported by the author (Puckett 2020) (adapted from Adams and Rhodes 2019b and Puckett 2021).

lake, I targeted shoreline and beach features near 1,237.5 masl along with the modern river channel and abandoned river channels below 1,237.5 masl. Elevations north of the lake above 1,237.5 masl were not surveyed because this was the limit of the permit area.

East of the lake, I targeted beach-ridge features at and just below the Sehoo highstand at 1,338 masl. Artifact scatters were identified as sites if they contained at least 10 flakes or at least one tool (flaked-stone or ground-stone) and another artifact in a 10-m^2 area. The only exception was a scatter of five flakes associated with 10 charred faunal fragments. Artifact scatters not meeting these criteria were identified as isolates. Field crews identified and recorded 38 new sites.

For the purposes of identifying previously recorded precontact sites, the lower Walker Lake basin was defined as all drainage systems hydrographically below Mason Valley flowing directly into the lake or into the Walker River (Figure 4.1). Sites associated with drainage systems hydrographically above Mason Valley were removed to avoid including sites that could be primarily associated with the East Walker River, West Walker River, or Carson Sink rather than Walker Lake. I identified 100 previously recorded sites in this area. I then applied the criteria used in the field to this dataset (i.e., 10 flakes or at least one tool and another artifact in a 10 m^2 area) to determine which previously recorded sites could be compared to the 2014-16 sites. Twenty-four sites were classified as isolates and four did not have enough information for comparative analyses. Therefore, the analysis includes 72 previously recorded and 38 newly recorded sites, for a total of 110 sites in this study. Finally, to spatially correlate all sites used here, I created a point feature in ArcMap 10.6.1 for each of the 110 site-datum locations.

4.3.2. Lithic Technological Analysis

To address questions about landscape use and mobility in the Walker Lake basin, this study focuses on the distribution, through time and across space, of artifacts from sites in the dataset. Debitage is a valuable source of information regarding site activity and landscape adaptations; however, because this study relied heavily on sites recorded by others (65.4%), necessary details of debitage presence and type are unavailable. Therefore, this study focuses on non-debitage artifacts.

Specific artifact types can provide proximal information about the kinds of activities that occurred across space in the study area and can inform on technological organization, mobility levels, and settlement strategies. Eleven artifact types were consistently reported for all the sites in this study. These include core, biface, point, drill, scraper, flake tool, cobble tool, mano, metate, pestle, and net weight. Fragments of these artifact types were each included as single instances of a type because refit information was rarely recorded. Because my database includes inconsistent classifications used by various site recorders, the “flake tool” type consists of numerous subtypes, including edge-modified flake, retouched flake, utilized flake, and graver. The “cobble tool” type includes the subtypes: hammer stone, chopper, and battered cobble. For general artifact class distribution analyses, I consolidated several of these types into the following artifact classes: core, biface (bifaces and drills), point, uniface (scrapers and flake tools), ground stone (manos, metates, pestles, and net weights), and cobble tool.

Artifact types reflect various levels of lithic tool curation, resource processing, and primary versus secondary lithic reduction. For instance, bifaces, projectile points, and drills require more time for production, planning and preparation than flake tools and unifaces. Points and drills are also generally associated with specialized activities such as hunting and perforation, whereas bifaces are often ideal for generalized use. Flake tools and battered cobbles are expedient tools that require little planning and can be quickly produced given toolstone availability. They may be applied to a wide range of resource processing or production activities (Andrefsky 2005). Ground and shaped stone artifacts such as net weights, while associated with specialized resource processing/procurement, are generally considered to be not expediently made nor very portable, tethering them relatively closely to the landforms where they were used but not necessarily manufactured (Hannold 2019; Simms 1983b; Stone 1994; Tuohy 1968; Zeanah 2002). While each of the artifact types identified provides some information about landscape use and site type, the number of different artifact types on a given site also acts as a proxy for the number of different activities that occurred on a site. Sites with more artifact types, and therefore, more activities tend to represent sites that were occupied longer and by more people, such as residences or base camps. In contrast, sites with less artifact-type diversity, hence less activities, tend to represent shorter stays with fewer people, such as logistical sites (Graf 2010; Kuhn 1995). In a general sense, more activities tend to indicate less mobility (Binford 1979), and together with analyses of within-site and between-site artifact variability, a framework for mobility strategies used in the Walker Lake basin can be constructed.

Therefore, the artifact classes and types defined above were worked into a few other groupings and used in comparative analyses to explore four variables, informing on technological organization and provisioning strategies in the Walker Lake basin: reduction activities, tool production, task activities, and site type. To explore reduction activities, I used the frequency of all cores compared with all flaked-stone tools to assess the degree of primary reduction technologies and activities versus secondary reduction technologies and activities. Cores represent primary-reduction activities and flaked-stone tools represent secondary-reduction activities. To determine the relative effort put into tool production and to compare site toolkits reflecting provisioning of individuals (formal tools) versus provisioning of places (informal tools), I combined all bifaces, projectile points, drills, and scrapers into a “formal tool” category and all flake tools and cobble tools into an “informal tool” category. These two groupings compare the relative time and curation efforts that went into artifact production, with formal tools requiring more time, effort, and planning and informal tools needing less. To explore what types of task activities were being performed at sites, I combined a number of artifact classes into three “task” classes. I combined biface and point counts to represent hunting tasks. In this case, bifaces and points are associated with the full range of hunting activities, including gearing up and replacement that may precede or follow hunting, raw-material needs during hunting, and the activities tied to the logistical hunting forays themselves (Gore and Graf 2018; Kelly 1988). I combined flake tools, scrapers, and drills to represent tasks related to initial processing activities generally performed at short-term camp sites (Fuentes et al. 2019; Jew et al. 2013; Shott 1989). Finally, I combined all manos, metates, pestles, and net weights to represent tasks related to more time-intensive and energy-intensive, resource-procurement and resource-processing activities at long-term camp sites, but not generally associated with individually-provisioned toolkits (McGuire and Hildebrandt 1994; Rhode et al. 2004; Wohlgemuth 1996, Zeaneh 2002, 2004).

To approximate site type, I assessed the number of activities present at each site by calculating relative artifact-class variability. I ranked sites by the number of artifact classes they had: sites with ≤1 artifact class, sites with 2 artifact classes, and sites with ≥3 artifact classes. To generally assess the extent of on-site activities and ultimately the site type, sites with ≤1 artifact class were labeled "single use" sites and ranked 1, those with 2 artifact classes were labeled "moderate use" sites and ranked 2, and those with ≥3 artifact classes were labeled "diverse use" sites and ranked 3. This distribution is useful for comparing the extent of site use and exploring the nature of provisioning and mobility on the landscape.

4.3.3. Archaeological Site Chronology

Time in this study is controlled through a relative chronology based on the presence of temporally diagnostic projectile points identified at 33 of the 110 sites. It is less than ideal because it consists entirely of surface sites that cannot be radiocarbon dated. In the Walker Lake basin, cycles of deposition and erosion have promoted the formation of archaeological lag deposits while areas with minimal sediment deposition allow for landforms and sites to remain visible across multiple periods (cf. Grayson 2011). As a result, surface sites may often be palimpsests that conflate multiple activities across different times. Despite this limitation, the presence of chronologically diagnostic points provides a valuable proxy record for landscape use at different times. For this reason, I focus on the relationship between the landscape and dated sites using diagnostic artifacts, comparing these relationships to the number of artifact types at sites from different ages.

For my chronology, projectile-point types were classified using standard Great Basin typologies (Beck and Jones 1997; Butler 1965; Layton 1970; Madsen et al. 2015; Rice 1972; Thomas 1981). I used Hildebrandt and King's (2002) point chronology for the Sierra-Cascade Front and categorized temporal periods using McGuire's (2002) framework (see Smith et al. 2017 for potential outliers). I have adjusted McGuire's Paleoindian chronology to reflect subsequent research concerning the Western stemmed point chronology (Goebel and Keene 2014). I acknowledge that some (e.g., Beck and Jones 2010; Brown et al. 2019) critique this chronology and Brown et al. (2019) raise concerns with the later periods of stemmed-point dating and sampling. However, Goebel and Keene provide a strong foundation for the Western stemmed-point chronology based on the best available data. The chronology is as follows: Paleoindian, including western stemmed and western fluted points (human entry-9,000 cal BP); Early Holocene/Post-Mazama, including Pinto and Large Side Notched Points (9,500-5,000 cal BP); Early Archaic including, Gatecliff and Elko Series points (5,000-3,500 cal BP); Middle Archaic, including Gatecliff, Humboldt, and Elko points (3,500-1,350 cal BP); Late Archaic, including Rose Spring and Eastgate points (1,350-600 cal BP); and Late Prehistoric, including Desert Series points (600 cal BP-contact). While Hildebrandt and King's (2002) point chronology indicates some overlap between the different components, here I have combined McGuire's (2002) period chronology with the points in question to approximate periods with points. I also highlight that my point-to-period correlation closely aligns with Hockett and Murphy's (2009) point chronology for the north-central Great Basin. Because the point chronology does not limit Elko, Humboldt, and Gatecliff points to a single temporal period, sites with these points were labeled Early-Middle Archaic. Therefore, I developed a set of five archaeological "age components" for comparison in the Walker Lake basin: Paleoindian, Early Holocene/Post-Mazama, Early-Middle Archaic, Late Archaic, and Late Prehistoric. For Kruskal-Wallis H and Mann-Whitney tests (see statistical methods below) comparing artifact classes and variables by age components I applied an ordinal scale with the oldest period ranked 1 and successive periods given the next largest rank.

Eleven of the 33 sites in this analysis with temporally diagnostic artifacts contained points from more than one age component (Appendix C: Table C.1). While these sites cannot be assigned a specific age, temporal artifacts act as proxies for occupation during specific periods. As such, I included each age component from multiple-period sites when comparing ages to the Walker Lake basin landscape. For my analyses comparing ages and analytical variables associated with tool counts, I only included artifacts from the 22 sites with a single age component.

4.3.4. Spatial Analysis Methods

To analyze landscape use, I established two sets of landscape categories, one based on elevation range and the other on landform types (Appendix C: Table C.2). I identified the elevation of site datums using a USGS digital elevation model (DEM) of the Walker Basin (Lopes and Smith 2007) that I imported into ArcGIS 10.6. A small number of the 110 sites fell outside the DEM: for these, elevation was estimated based on the contours from 7.5’ USGS maps, available as a free resource in ArcGIS 10.6. Once I identified the elevation of each site datum, sites were separated into three groups based on their location within an elevation range: below the historic highstand (< 1,252 masl), between the historic highstand and the Sehoo highstand (1,252-1,338 masl), and above the Sehoo highstand (> 1,338 masl). These groups allowed me to associate sites that must have been occupied during relatively low lake levels, that could have been used during most of the Holocene and were not restricted to periods with low lake levels, and that were related to more upland environments. For Kruskal Wallis H and Mann Whitney tests comparing artifact classes and variables by elevation, I used an ordinal ranking for the elevation ranges where below the historic highstand = 1, between the historic and Sehoo highstand = 2, and above the Sehoo highstand = 3.

I identified three primary landform types ideal for analyzing landscape use and site distribution within the Walker Lake basin: those associated with washes surrounding the basin, those found along the Walker River, and those associated with Walker Lake. Washes were defined as ephemeral drainages that do not contain perennial water and identified on USGS 7.5 minute maps using v-shaped topographic lines. Lake features were defined as linear ridges of coarse sands sitting at a consistent elevation within the basin. River features were defined as either the modern river channel or generally north-south running linear channel beds visible from satellite imagery. In the analyses, these features are labeled wash, river, and lake, respectively. They were selected because their unique characteristics are key for investigating technological organization and mobility. The lake represents the primary perennial water system in the region (Fowler 1990; Fowler and Bath 1981). The river is also a major perennial water source, but being fluvial, is less consistent, variably avulsed into the Carson sink or Walker Lake, and is correlated with different environmental resources (e.g., willows and fish spawns) (Fowler 1990; Fowler and Park 1989). Washes are associated with higher elevations and intermittent water availability. They also provide natural cover for hunting, seasonally attract game, are associated with a variety of unique food resources, and can often be a source of eroding toolstone material (Babel et al 2012; Fowler 1992; Riddel and Tuohy 1978; Steward and Wheeler 1974).

Prior to affiliating each site in this study with a given landform type, I created numerous shapefile features within ArcGIS to facilitate my analysis. Using a combination of satellite imagery and USGS 7.5' topographic maps, I created shapefiles for the modern Walker River, abandoned Walker River channels, and washes across the Walker Lake basin. Using historical lake-level data from Adams (2007) and Adams and Rhodes (2019b), I created line shapefiles for Walker Lake at a range of elevations representing the variable nature of the lake for the last 15,700 years. These included the Sehoo highstand, the Holocene highstand (1,262 masl), the historic highstand, the 1882 lake highstand (1,246.3 masl), the lake level associated with the lake landform surveyed in 2015-16 (1,232.9 masl), and the spring 2019 lake level (1,994 masl). Using the "Near" tool in ArcMap, I calculated the distance between each site datum and the nearest wash, river channel (modern or abandoned), and lake level. I only included the Sehoo highstand feature for sites with a Paleoindian component. Otherwise, all lake distances were measured exclusively to Holocene-aged lake-level features. I assigned sites to a wash, river, or lake landform type based on a combination of position and proximity to these features (Figure 4.3).

One challenge with using the closest landform to categorize sites is the fact that Walker Lake has had a range of elevations from 1,262 masl to 1,178 masl during the last 5500 years (Adams and Rhodes 2019b; Puckett 2021). As a result, 35 of the sites recorded between 2014-2016 could have been on the shore of the lake at several times during the Holocene: this includes 13 of the 16 sites categorized as “river sites.” I maintained the “river site” categorizations because these sites were all identified in direct correlation with either the modern river or an abandoned river channel. None of the “river sites” were associated with a preserved lacustrine feature or landform. Finally, two of the 110 sites were found in the Gillis Range uplands and could not be clearly affiliated with any of the three landform categories. I removed these sites and their two associated artifacts from analyses focused on landforms types.

To address the relationship between landscape use and age components irrespective of artifact assemblage, I compared the landform-type and elevation-range categories for the 33 sites with age components. Because site presence by age did not assume specific details about artifact counts, I was able to use all of the components, including those sites with multiple components. This allowed me to compare the landscape distributions of 47 separate age components across the 33 sites.

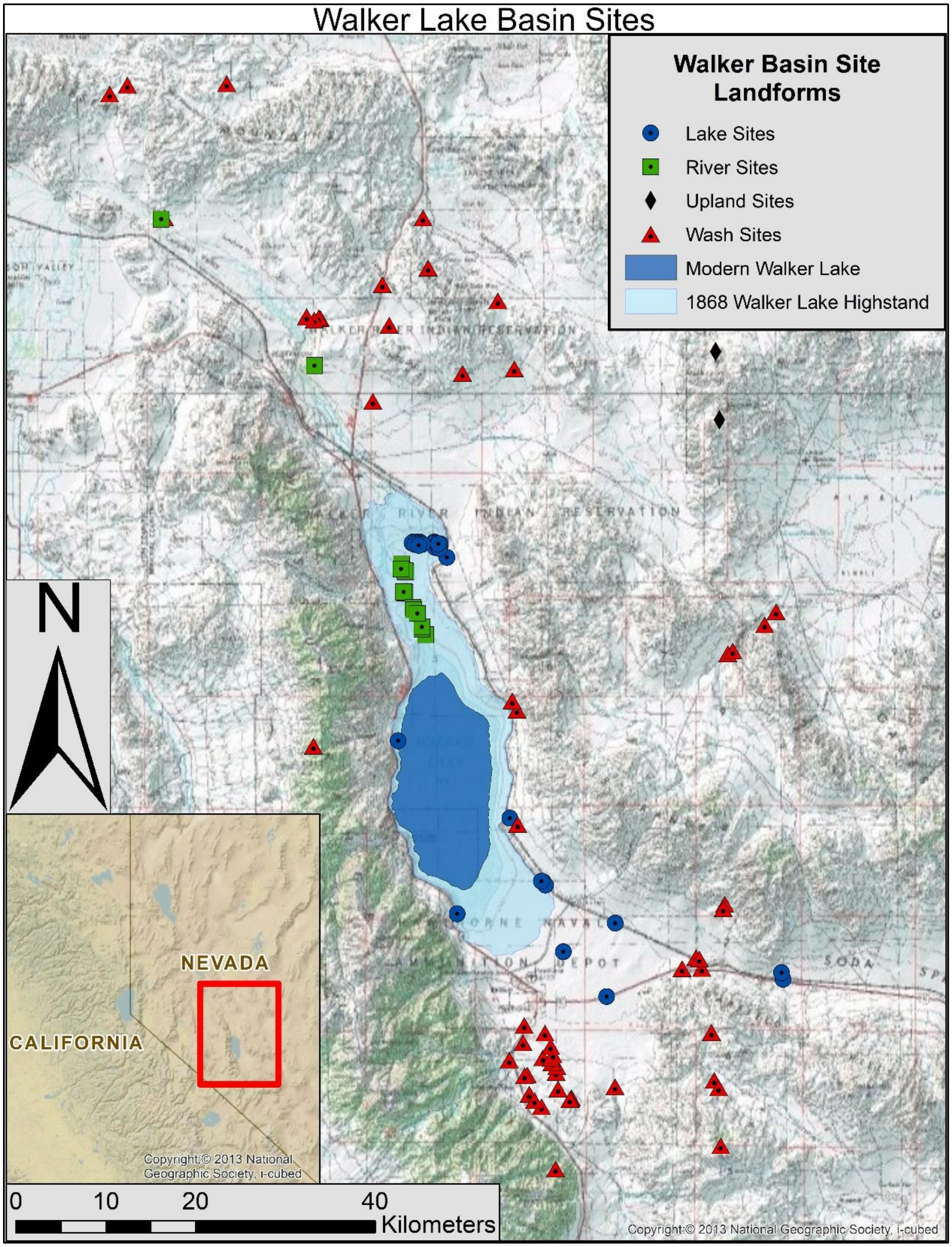

Figure 4.3. Sites identified in the Walker Lake basin associated with their landform types. The two sites associated with the uplands are not included in landform type analyses. Topographic basemap (National Geographic Society 2013) and inset map (ESRI 2017) modified by author in ArcMap 10.6.

4.3.5. Statistical Analyses

Basic descriptive variables comparing the lithic-artifact dataset, artifact types by time and landscape, were calculated in Microsoft Excel. I used the R statistical program (version 3.6.2) within the RStudio environment (version 1.2.5033) to analyze the descriptive variables: artifact class by age component, landform type, and elevation range as well as site age component by landform type and elevation range. I also used R to test the integrative variables identified above by age component, landform type, and elevation range. These variables include reduction activities (primary, secondary), tool production (formal, informal), task activity (hunting, initial resource processing and use, intensive resource processing and use), and site type (single-use, moderate-use, and high-use) (see Appendix D for R script used to run statistical tests).

Because the data are not normally distributed, I used a series of non-parametric tests. Chi-square tests were used to compare sets of nominal-scale variables, including the comparisons of age components, artifact class, reduction activities, tool production, and task activities, to landform type. For chi-square tests where the expected count was too low (> 20% of cell counts were lower than 5), I used a Fisher's Exact test. I used the Kruskall Wallis H test when analyzing ordinal-scale data with multiple groupings. In other words, I used this test to analyze the variable groupings of artifact class and task activities by the ordinal-scale variables of age component and elevation, to analyze age component by elevation rank, and to analyze age component, landform type, and elevation range by site type. I used the Mann-Whitney U test when analyzing variables with only two groupings (i.e., reduction activities and tool production,) by ordinal-scale variables (i.e., age component and elevation rank). Due to the different distributions of data across the various categories and variables, all Kruskal Wallis H and Mann-Whitney U tests compared mean ranks. For all Kruskal Wallis H tests, I used the post-hoc Dunn's multiple comparisons test to compare the statistical differences between the categorical variables. I used R package "dunn.test" in combination with R package "FSA" (Fisheries Stock Assessment) to run these analyses (Dinno 2017; Ogle et al. 2020). Dunn test p-values were corrected using the Holm-Šidák adjustment (Dinno 2017).

4.4. Results

As discussed above the dataset includes 110 sites. By elevation, 41 sites are located below the historic highstand, 20 sites are located between the historic highstand and the Sehoo highstand, and 49 sites are positioned above the Sehoo highstand. Because two sites are located high above the highstand in the uplands of the Gillis Range, only 108 are associated with a lake, river, or wash landform type. For these, there are 33 lake sites, 16 river sites, and 59 wash sites. Thirty-three sites include at least one temporally diagnostic artifact, but only 22 of these sites are associated with a single temporal component. The total number of age components is 47, including eight Paleoindian, 0 Early Holocene/Post-Mazama, 13 Early-Middle Archaic, 10 Late Archaic, and 16 Late Prehistoric. Single-component-site ages are distributed as follows: five Paleoindian, five Early-Middle Archaic, three Late Archaic, and nine Late Prehistoric (see Appendix C: Table C.1 for sites with temporal components). Because no

Early Holocene/Post-Mazama sites were found, this time period is excluded from the analyses below. Only sites and associated artifacts with a single temporal component were included in the statistical analyses for artifact types and counts.

4.4.1. Spatial Distribution of Age Components

I analyzed the distribution of all age components represented by the 33 sites with temporally diagnostic artifacts relative to landform type and elevation range (Figure 4.4; Appendix E: Tables E.1-E.2). Comparing the distribution of age components by landform type shows a statistically significant difference in time of human occupation relative to landscape location. Though the same number of Paleoindian occupations were found associated with both the lake and washes, it appears Paleoindians selected washes far more than expected and the river far less than expected, while the lake was used as expected. During the Early-Middle Archaic period, lake sites were used less than expected, while the river and washes were more commonly used. Late Archaic occupations appear less than expected near the lake and washes but were placed more commonly near the river. Finally, during the Late Prehistoric period, lake sites were selected more than expected, yet the river and washes were not. I also compared the distribution of sites with age components on different landforms using a Kruskal Wallis H test in which the landforms were compared by the number of associated site components with different ages. This test was not statistically significant, but mean ranks show that the lake was preferentially used during later periods whereas the river and washes tend to have a similar age distribution. Even though the washes and lake

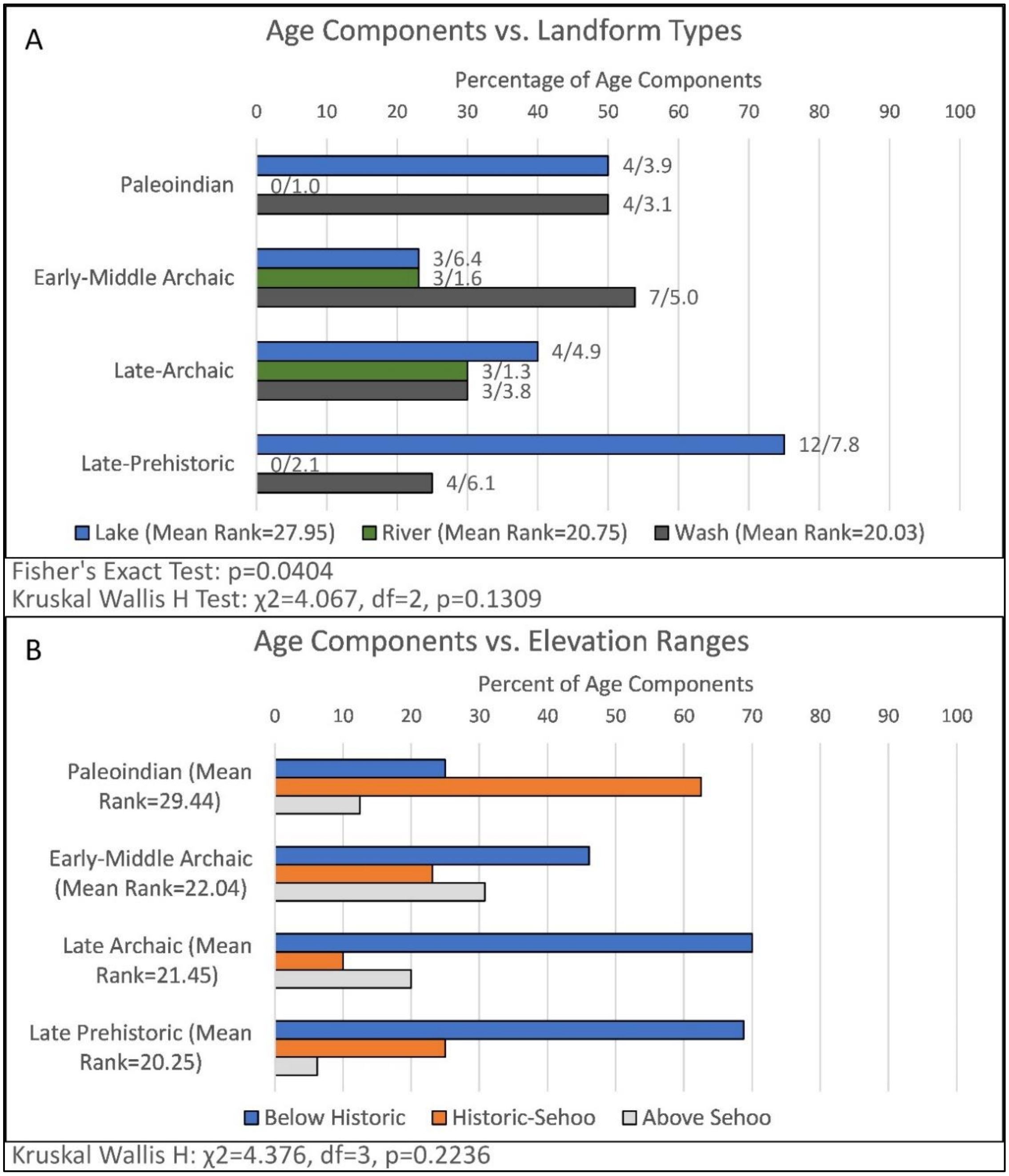

Figure 4.4. Age component by A: landform type and B: elevation range. Note: mean rank of landform types and contingency-table count/expected count for each age is given in chart A. Mean rank of ages is given in chart B.

were used throughout time and the river was only used from the Early to Late Archaic, these tests indicate some preferences in use with an overall pattern of shifting focus from washes to river to lake through time.

In contrast to comparisons of age components by landform type, examination of age component by elevation range expresses stochastic homogeneity with no statistically significant patterns. Frequency and mean-rank values show Paleoindian sites tend to be located higher in elevation compared with later sites with 75% found at high-middle elevations. During the Early-Middle Archaic, sites were positioned at high-middle elevations about 54% of the time and at low elevations about 46% of the time. During the Late Archaic and Late Prehistoric periods, sites were more regularly placed at low elevations (70% and 69%, respectively). Thus, there is a notable increase in use of lowland settings from the Paleoindian to Early-Middle Archaic, and another dramatic increase in use of the lowlands from the Early-Middle Archaic to the Late Archaic. Change in mean ranks, however, signals a more nuanced pattern of use between middle and higher elevations from the Early-Middle Archaic through the Late Prehistoric with site use more common at high-elevation locations during the Archaic and slightly more use of the middle elevations during the Late Prehistoric.

In sum, the lake was used more often than expected during the Late Prehistoric period. The river appears to have been preferred throughout the entire Archaic period with more-than-expected occupations dating to both the Early-Middle and Late Archaic found along the river. Washes were preferentially selected during the earliest periods, the Paleoindian and Early-Middle Archaic. Finally, while not statistically significant, a simple, yet poignant, pattern is present, one of landscape use in the Walker Lake basin that became gradually more focused on lower elevations through time.

4.4.2. Artifact Distributions

From these 110 sites there are 434 artifacts, including 364 flaked-stone pieces and 70 ground-stone pieces. The distribution of these artifacts by age component, landform type, and elevation range are shown in Tables 4.1-4.3 below. Table 4.1 presents all artifacts recorded from sites with an age component, with all artifacts from multi-component sites grouped together. While 309 artifacts are from sites with a temporal component, 140 are from multi-component sites and only 169 are from single-component sites. Table 4.2 shows the distribution of artifacts associated with lake, river, and wash landform types, with only 432 of the 434 total artifacts included in these analyses. Table 4.3 shows the distribution of artifacts by elevation range and includes the full set of 434 artifacts. These three tables provide a breakdown of specific artifact types associated with the different age and landscape categories investigated in this study.

Table 4.1. Frequency of artifacts organized by type and time.

	Archaeological Components					
Artifact Types	**Paleoindian**	**Early-Mid Archaic**	**Late Archaic**	**Late Prehistoric**	**Multi-Component**	**Total**
Core	3 (7.5%)	6 (15.0%)	1 (2.5%)	16 (40.0%)	14 (35.0%)	**40 (12.9%)**
Biface	13 (14.3%)	10 (11.0%)	6 (6.6%)	19 (20.9%)	43 (47.3%)	**91 (29.4%)**
Point	12 (16.7%)	9 (12.5%)	5 (6.9%)	14 (19.4%)	32 (44.4%)	**72 (23.3%)**
Drill	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)	**2 (0.6%)**
Scraper	1 (10.0%)	2 (20.0%)	1 (10.0%)	1 (10.0%)	5 (50.0%)	**10 (3.2%)**
Flake Tools	7 (13.7%)	4 (7.8%)	2 (3.9%)	17 (33.3%)	21 (41.2%)	**51 (16.5%)**
Cobble Tool	0 (0%)	1 (33.3%)	0 (0%)	1 (33.3%)	1 (33.3%)	**3 (1.0%)**
Mano	0 (0%)	0 (0%)	3 (20.0%)	7 (46.7%)	5 (33.3%)	**15 (4.8%)**
Metate	0 (0%)	0 (0%)	1 (5.6%)	1 (5.6%)	16 (88.9%)	**18 (5.8%)**
Pestle	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	**0 (0%)**
Net Weight	0 (0%)	0 (0%)	0 (0%)	6 (85.7%)	1 (14.3%)	**7 (2.3%)**
Total	**36 (11.6%)**	**32 (10.4%)**	**19 (6.1%)**	**82 (26.5%)**	**140 (45.3%)**	**309 (100%)**

Table 4.2. Frequency of types of artifacts by landform.

	Walker Lake Basin Landforms			
Artifact Types	**Lake**	**Wash**	**River**	**Total**
Core	41 (61.2%)	20 (29.9%)	6 (8.9%)	**67 (15.5%)**
Biface	43 (33.1%)	73 (56.1%)	14 (10.8%)	**130 (30.1%)**
Point	37 (51.4%)	25 (34.7%)	10 (13.9%)	**72 (16.7%)**
Drill	2 (66.7%)	1 (33.3%)	0 (0%)	**3 (0.7%)**
Scraper	7 (70.0%)	1 (10.0%)	2 (20.0%)	**10 (2.3%)**
Flake Tools	49 (65.3%)	18 (24.0%)	8 (10.7%)	**75 (17.4%)**
Cobble Tool	3 (60.0%)	2 (40.0%)	0 (0%)	**5 (1.2%)**
Mano	12 (46.1%)	4 (15.4%)	10 (38.5%)	**26 (6.0%)**
Metate	11 (31.4%)	13 (37.1%)	11 (31.4%)	**35 (8.1%)**
Pestle	1 (100%)	0 (0%)	0 (0%)	**1 (0.2%)**
Net Weight	7 (87.5%)	0 (0%)	1 (12.5%)	**8 (1.8%)**
Total	**213 (49.3%)**	**157 (36.3%)**	**62 (14.4%)**	**432 (100%)**

Table 4.3. Frequency of types of artifacts by elevation.

	Walker Lake Basin Elevations			
Artifact Types	**Below Historic**	**Historic-Sehoo**	**Above Sehoo**	**Total**
Core	43 (64.2%)	7 (10.4%)	17 (25.4%)	**67 (15.4%)**
Biface	37 (28.5%)	48 (36.9%)	45 (34.6%)	**130 (30.0%)**
Point	40 (55.5%)	17 (23.6%)	15 (20.8%)	**72 (16.6%)**
Drill	2 (66.7%)	0 (0%)	1 (33.3%)	**3 (0.7%)**
Scraper	8 (80.0%)	2 (20.0%)	0 (0%)	**10 (2.3%)**
Flake Tools	55 (71.4%)	11 (14.3%)	11 (14.3%)	**77 (17.7%)**
Cobble Tool	3 (60.0%)	0 (0%)	2 (20.0%)	**5 (1.2%)**
Mano	17 (65.4%)	6 (23.1%)	3 (11.5%)	**26 (6.0%)**
Metate	18 (51.4%)	7 (20.0%)	10 (28.6%)	**35 (8.1%)**
Pestle	1 (100%)	0 (0%)	0 (0%)	**1 (0.2%)**
Net Weight	8 (100%)	0 (0%)	0 (0%)	**8 (1.8%)**
Total	**232 (53.4%)**	**98 (22.6%)**	**104 (24.0%)**	**434 (100%)**

Tables 4.4-4.6 show the distribution of the artifact classes relative to age component, landform type, and elevation range. These tables also show the results of statistical tests for age component, elevation range, and landform types. In Table 4.4, a Kruskal Wallis H test shows statistically significant differences between artifact class and age component. The mean-rank values indicate unifaces, ground stones, and cores are more common during later periods while points are more common earlier in time. Bifaces are relatively common throughout time. Post-hoc Dunn's tests indicate significant differences between ground stones and bifaces and between ground stones and points. Though most artifact classes are found through time, ground stone is only found in late Holocene contexts. Table 4.5 shows statistically significant differences between artifact class and landform types using a chi-square test. Generally, cores and unifaces are more common near the lake, ground stone is more common near the river,

Table 4.4. Artifact class by age components.

	Archaeological Component					
Artifact Class	**Paleoindian**	**Early-Middle Archaic**	**Late Archaic**	**Late Prehistoric**	**n**	**Mean Rank**
Core	3 (11.5%)	6 (23.1%)	1 (3.8%)	16 (61.6%)	26	96.33
Biface	13 (27.1%)	10 (20.8%)	6 (12.5%)	19 (39.6%)	48	76.56
Point	12 (30.0%)	9 (22.5%)	5 (12.5%)	14 (35.0%)	40	64.29
Uniface	8 (22.9%)	6 (17.1%)	3 (8.6%)	18 (51.4%)	35	86.00
Cobble Tool	0 (0%)	1 (50.0%)	0 (0%)	1 (50.0%)	2	90.50
Ground Stone	0 (0%)	0 (0%)	4 (22.2%)	14 (77.8%)	18	117.28
Total	36	32	19	82	169	

Kruskal Wallis H: χ^2=15.53, df=5, p-value<0.0083
Dunn Test (Ground Stone-Biface): Z=-3.232, p-value (adjusted)= 0.0171
Dunn Test (Ground Stone-Point): Z=3.493, p-value (adjusted)= 0.0071

Table 4.5. Artifact class by landform types.

		Landform Type			
Artifact Class		**Lake**	**River**	**Wash**	**Total**
Core	**Count**	41	6	20	67
	Expected Count	33.0	9.6	24.4	67.0
	% Column Total	19.2	9.7	12.8	15.5
Biface	**Count**	45	14	74	133
	Expected Count	65.6	19.1	48.3	133.0
	% Column Total	21.1	22.6	47.1	30.8
Point	**Count**	37	10	25	72
	Expected Count	35.5	10.3	26.2	72.0
	% Column Total	17.4	16.1	15.9	16.6
Uniface	**Count**	56	10	19	85
	Expected Count	41.9	12.2	30.9	85.0
	% Column Total	26.3	16.1	12.1	19.7
Cobble Tool	**Count**	3	0	2	5
	Expected Count	2.5	0.7	1.8	5.0
	% Column Total	1.4	0.0	1.3	1.2
Ground Stone	**Count**	31	22	17	70
	Expected Count	34.5	10.0	25.4	69.9
	% Column Total	14.6	35.5	10.8	16.2

Table 4.5. Continued

Artifact Class		Lake	River	Wash	Total
Total	**Count**	213	62	157	432
	Expected Count	213.0	61.9	157.0	431.9
	% of Total	49.3	14.4	36.3	100.0

χ2=53.567, df=10, p-value=<0.0001

Table 4.6. Artifact class by elevation ranges.

	Elevation				
Artifact Class	**Below Historic**	**Historic-Sehoo**	**Above Sehoo**	**n**	**Mean Rank**
Core	43 (64.2%)	7 (10.4%)	17 (25.4%)	67	201.23
Biface	39 (29.3%)	48 (36.1%)	46 (34.6%)	133	268.05
Point	40 (55.6%)	17 (23.6%)	15 (20.8%)	72	210.88
Uniface	63 (72.4%)	13 (14.9%)	11 (12.7%)	87	174.79
Cobble Tool	3 (60.0%)	0 (0%)	2 (40.0%)	5	222.90
Ground Stone	44 (62.8%)	13 (18.6%)	13 (18.6%)	70	196.54
Total	232	98	104	434	

Kruskal Wallis H: χ^2=42.558, df=5, p-value<0.0001
Dunn Test (Biface-Core): Z=3.922, p-value (adjusted)=0.0011
Dunn Test (Biface-Ground Stone): Z=4.258, p-value (adjusted)=0.0003
Dunn Test (Biface-Point): Z=3.436, p-value (adjusted)=0.0071
Dunn Test (Biface-Uniface): Z=5.948, p-value (adjusted)=<0.0001

and bifaces are more common near washes. Cobbles and points express no significant relationship to landform type; however, cobbles were only found in lake and wash contexts, while points were found associated with lake landforms more than expected and in wash contexts less than expected. Finally, Table 4.6 shows Kruskal Wallis H results analyzing artifact class by elevation range. Mean rank values indicate cores, ground stones, and unifaces are mostly found at lower elevations. Bifaces are more common at higher elevations. Cores and cobble tools are more common at lower and higher elevations, but less frequent at middle elevations. Finally, points trend from most common at lower elevations to least common at higher elevations, though these differences are not great compared with the other artifact classes. Post-hoc Dunn's tests indicate the significant differences are found in four places, between bifaces and cores, between bifaces and ground stones, between bifaces and points, and between bifaces and unifaces.

In sum, the data and statistical results shown across these three tables highlight a strong correlation between artifact class and age component, landform type, and elevation range. Bifaces and points tend to be used at higher elevations and near ephemeral landforms during the earliest periods, while cores, unifaces, and ground stones were more often selected during later periods at lower elevations near perennial water. Cobble tools do not have a strong signal, but these tend to be found higher and later near both washes and lake features.

4.4.3. Characterizing Reduction Activities

Three variables characterize lithic reduction strategies: age component, landform type, and elevation range (Figure 4.5). Though none of these comparisons are statistically significant, some patterns in the data are visible. First, comparisons of reduction strategies by age indicate that primary reduction took place more often than expected during the Late Prehistoric. Examining the distribution of reduction strategies by landform type, primary reduction appears to have taken place more often than expected near the lake, whereas secondary reduction seems to have transpired more

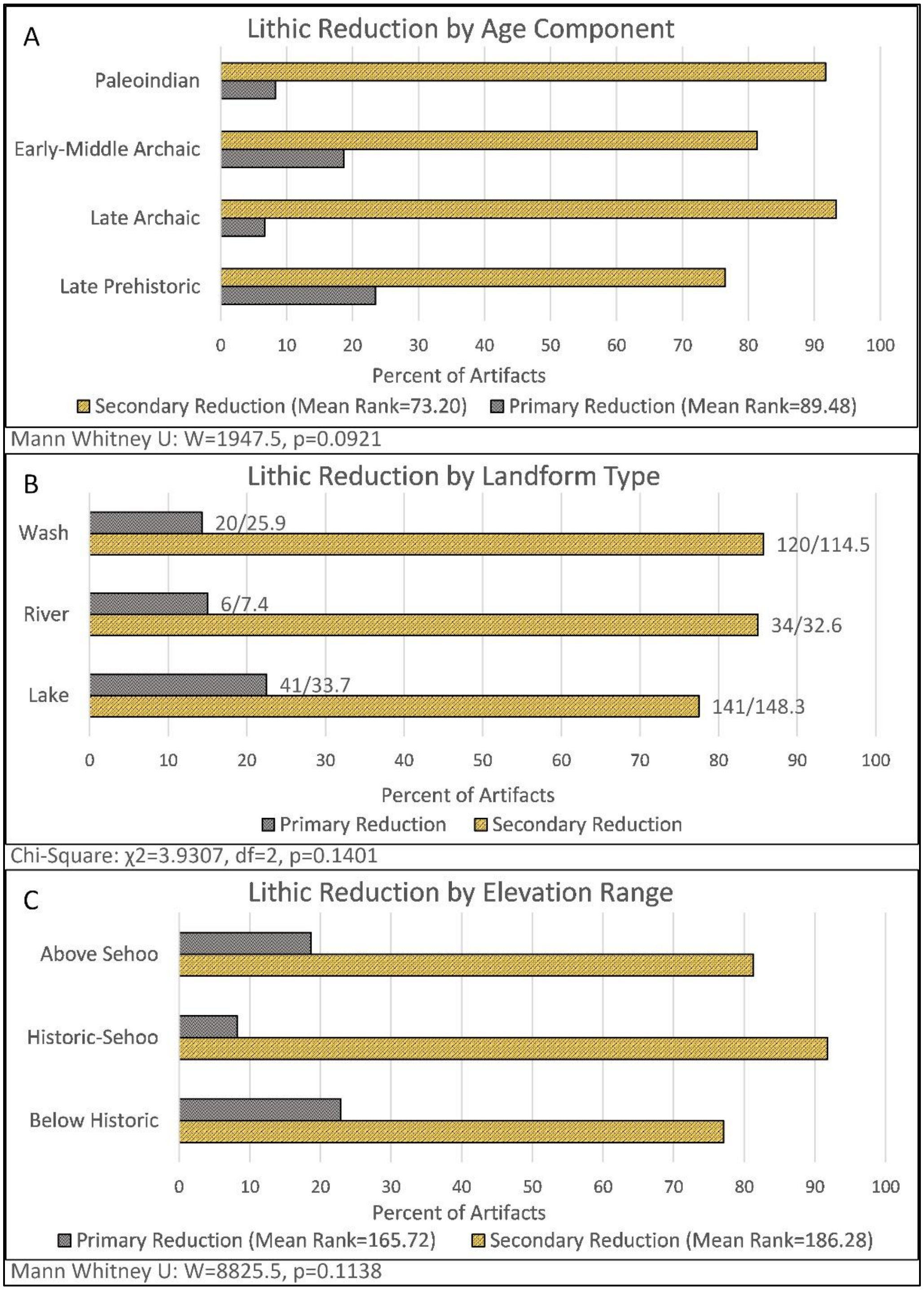

Figure 4.5. Primary and secondary reduction by A: age component, B: landform type, and C: elevation range. Note: mean rank of primary and secondary reduction is given in charts A and C; contingency-table count/expected count is given for each landform type in chart B.

than expected near the river and surrounding washes. The bar chart for reduction strategies by elevation also shows a slight increase in primary reduction at lowland sites with an increase in secondary reduction at sites located in middle-high elevations. Overall, there is a trend of secondary reduction activities being more common during earlier periods and being found on higher landforms associated with ephemeral water sources. Cores and primary reduction activities are more common during later periods and found on lower landform types associated with perennial water sources.

4.4.4. Tool Production

I analyzed tool production by comparing formal and informal tools against three variables: age component, landform type, and elevation range (Figure 4.6). Though no significant relationship between tool production and time was observed, and the frequencies of formal tools were consistently higher than informal tools throughout time, an interesting pattern was discerned. There is a slight trend in increased formal tool use and decreased informal tool use from Paleoindian through Archaic, but then a noticeable drop in the manufacture of formal tools and increase in informal tools during the Late Prehistoric period. Formal tools were more common than expected near washes and the river and less common than expected near the lake. The opposite is true of informal tools. Formal tools clearly increased in importance in middle-to-high elevations. In contrast, informal tools were significantly less important at these high elevations and valued more at lower-elevation locations. Overall, then, formal tools tend to be more common earlier in time, at higher elevations, and near more ephemeral features.

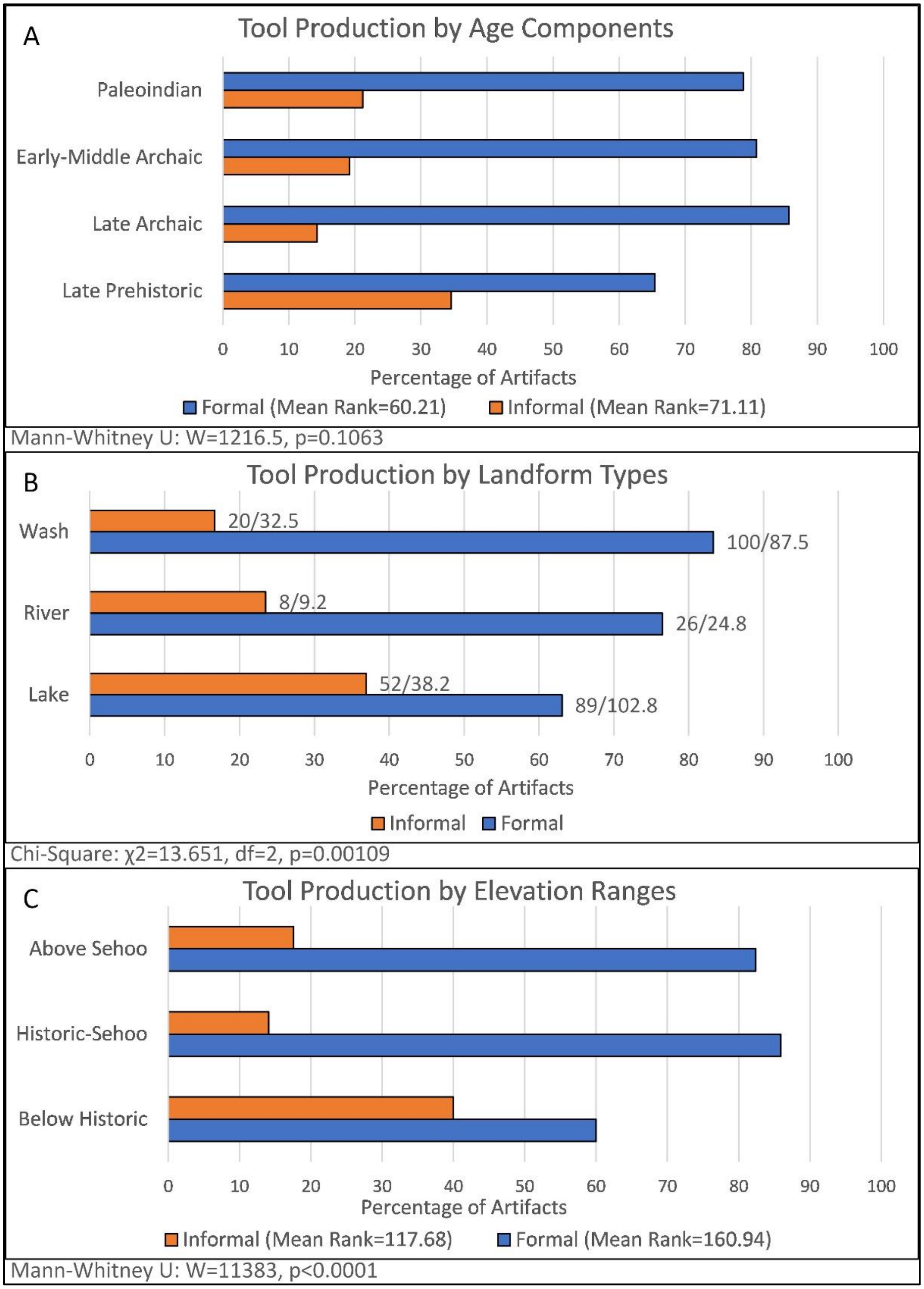

Figure 4.6. Tool production by A: age component, B: landform type, and C: elevation range. Note: mean rank of tool production is given in charts A and C; contingency-table count/expected count is given for each landform type in chart B.

Informal tools occur more commonly during later periods and at lower elevations near the lake.

4.4.5. Task Activities

To consider changes in foraging activities through time and space, I analyzed the number of tools associated with hunting, initial processing, and intensive processing tasks by age component, landform type, and elevation range (Figure 4.7; Appendix E:Tables E.11-E.15). Kruskal Wallis H and Dunn's post-hoc tests show statistically significant differences in task activities through time. Mean-rank values indicate hunting activities were more common in earlier periods. Intensive processing only occurred during the Late Archaic and Late Prehistoric periods with initial or light-processing tasks occurring throughout all time periods at low levels. Though more than 50% of the tasks transpiring at Late Archaic and Late Prehistoric sites were related to hunting, these tasks were balanced with processing tasks, especially with activities centered around more intensively processing resources. A chi-square test shows hunting tasks were more common than expected near washes, but less common than expected around the river and lake. Initial processing tasks were less common than expected near washes and the river, but more common near the lake. Intensive-processing tasks were less common than expected near washes, more common than expected near the river, and appear about as expected near the lake. Kruskal Wallis H and Dunn's post-hoc tests indicate that hunting-related tasks took place more often than expected at higher elevations, at or above the historic highstand of the lake. In contrast, both initial-processing tasks and

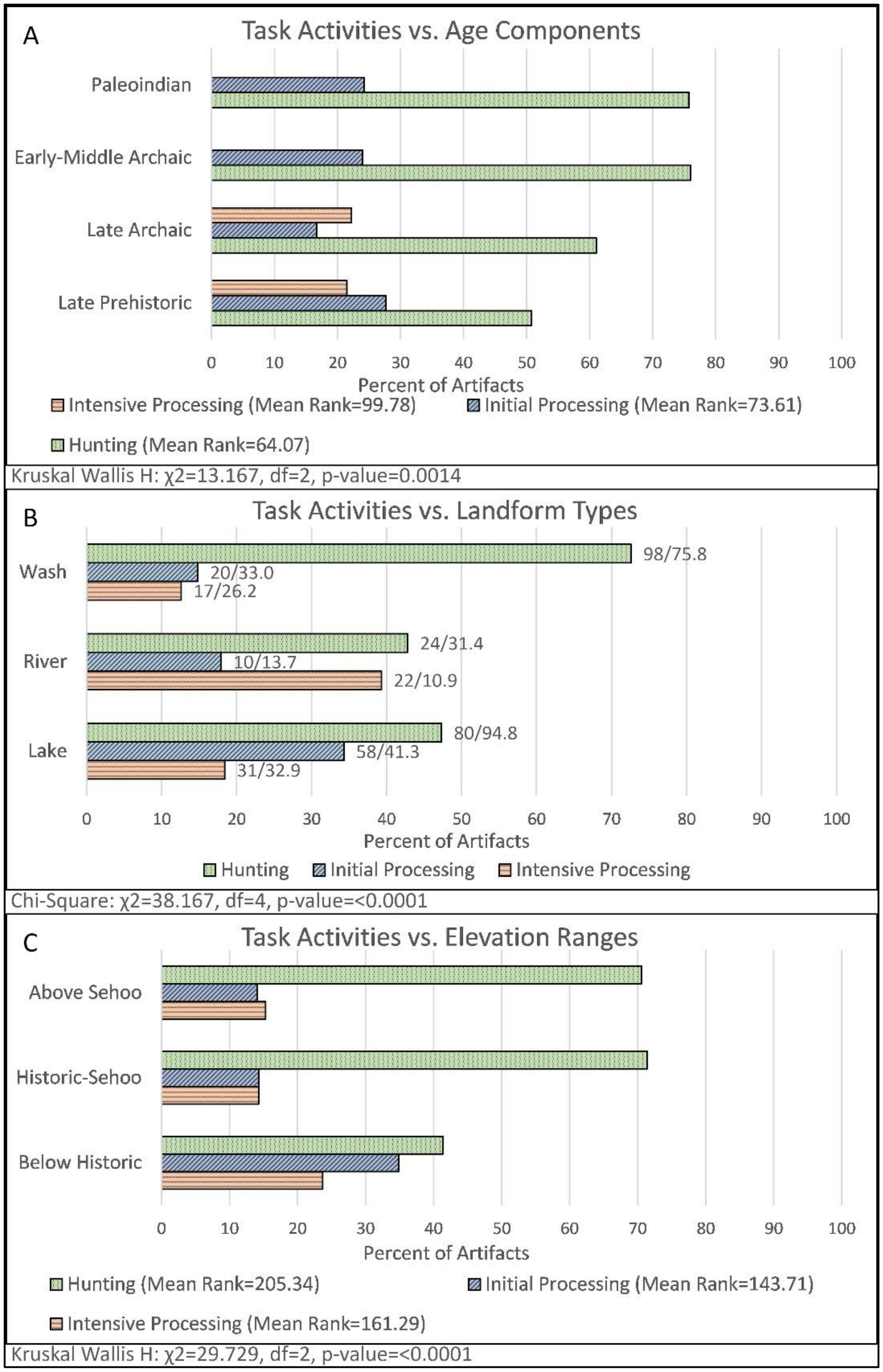

Figure 4.7. Task Activities by A: age component, B: landform type, and C: elevation range. Note: mean rank of task activities is given in charts A and C; contingency-table count/expected count is given for each landform type in chart B.

intensive-processing tasks transpired mostly at locations below this benchmark. In sum, the data indicate initial occupation of the Walker Lake basin focused on hunting and only later, especially during the Late Archaic and Late Prehistoric, did resource processing come into focus. With regards to space, hunting tasks took place most often near washes and at higher elevations, but processing tasks took place in lowland settings, both near the river and the lake.

4.4.6. Site Types

To better understand how foragers in the Walker Lake basin were using sites, I analyzed site type by age component, landform type, and elevation range (Figure 4.8; Appendix E:Tables E.16-E.21). The distribution of singe-activity sites, moderate-activity sites, and diverse-activity sites do not show statistical significance by age; however, there are some interesting patterns to highlight. Paleoindian and Early-Middle Archaic sites were sometimes single-activity sites; however, the difference between the two is that Paleoindian sites rarely express many activities whereas Early-Middle Archaic sites do. With regards to the Late Archaic and Late Prehistoric sites, almost none were single use sites. In contrast to time, comparisons of site type by landscape show statistically significant differences. Single-activity sites were located more commonly than expected near washes. Sites expressing moderate-to-diverse activities were found more commonly than expected near the lake and river. A similar pattern is found when comparing site types by elevation range. Sites above the Sehoo highstand were more often single-activity sites, whereas those situated below the Sehoo highstand were more often

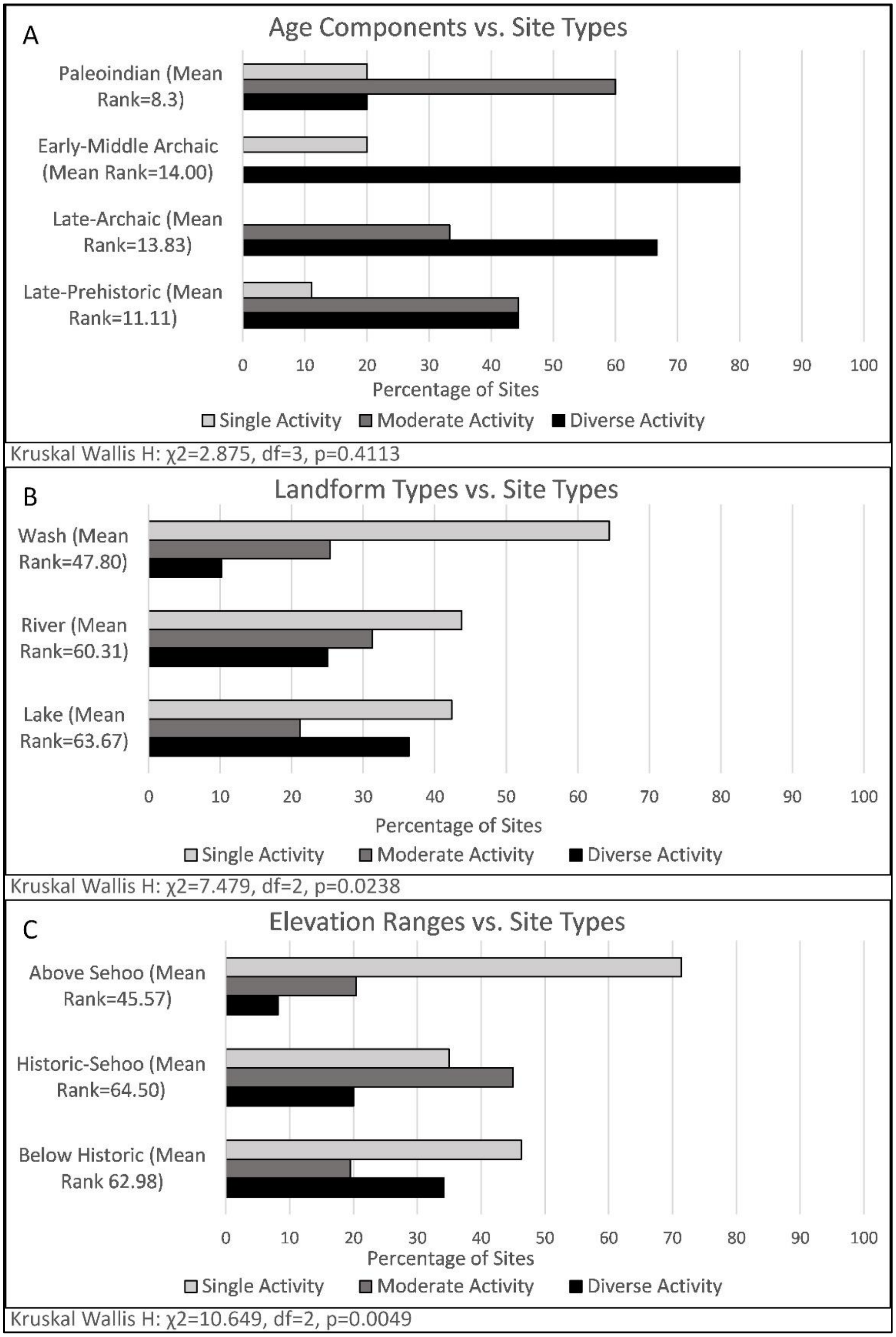

Figure 4.8. Site types by A: age component, B: landform type, and C: elevation range. Note: charts show mean ranks of site activity counts.

moderate-to-diverse-activity sites. In fact, sites with the highest activities were those found in the lowlands, below the historic highstand. In summary, the most diverse activities appear most among sites representing the most recent occupations and found in lowland settings, especially near the river and lake. In contrast, the earliest sites appear to represent more ephemeral use of the Walker Lake basin at higher elevations and washes.

4.5. Discussion

The null hypothesis (H_0) asserted that if populations associated with specific time periods did not exploit different landscapes or if there is no clear difference in technological organization relative to landscape use in the archaeological record, significant differences would not be observed between age distributions or lithic artifact distributions. The results of the statistical analyses provide multiple examples of statistically significant differences across both time and space, so the null hypothesis must be rejected. The tests support both alternative hypotheses: (H_1) populations expressed different preferences for landscape use and exploitation at different times because we see unique site locations and artifact distributions at sites associated with different age components; and (H_2) populations organized their mobility, adaptations, and technologies according the landscape because we see different artifact distributions and counts across the Walker Lake basin relative to different landscape categories. With these results, the patterns demonstrated across the statistical tests allow for an analysis of the Walker Lake basin archaeological record relative to mobility and technological organization. The resulting model for mobility and landscape use can then be compared to nearby sub-basins, models for Great Basin landscape exploitation, and the Walker Basin environmental record.

4.5.1. Landscape Use and Technological Organization

4.5.1.1. Age Components

The relationship between age components, landscape use, and technological organization is complex. A summary of the results from statistical analyses is provided in Table 4.7. Tests for age component distributions across the landscape only showed statistically significant differences using a Fisher's Exact test. Similarly, tests comparing technological organization and site artifact distributions were only significant by age when comparing artifact classes and site activities. Despite the limited number of significant results, the patterns observed across the age components help to understand how people used the Walker Lake basin through time.

Relative to later populations, Paleoindians concentrated their activities on higher elevations, making use of both lake features and washes. Since lake levels were low during this time, lake features likely provided excellent viewsheds of lower elevations while washes were more resource oriented, associated with seasonal water, hunting, and localized resources such as perennial grasses. Evidence for technological organization includes an emphasis on formal tools, low primary-reduction activities, and a focus on hunting activities. These activities are only combined with initial processing (e.g.,

Table 4.7. Overview of landscape and artifact category observations by age component.

	Age Components			
	Paleoindian	**Early-Middle Archaic**	**Late Archaic**	**Late Prehistoric**
Elevation	Mostly above the historic highstand	All elevations present; below historic highstand dominant	Primarily below historic highstand	Primarily below historic highstand
Landform	Lake and wash Landforms in equal use	Wash landforms dominant; lake and river equal use	Even landform distribution; lakes slightly dominant	Lake landforms dominate; no river use
Reduction Activities	Low primary reduction	Higher primary reduction	Lowest primary reduction	Highest primary reduction
Tool Production	High formal tools; informal tools well represented	Highest formal tools; fewer informal tools	High formal tools; lowest informal tools	Highest informal tools; formal tools dominant
Task Activities	Hunting dominant with some inntial processing	Hunting dominant with some initial processing	Hunting reduced; lowest initial processing; highest intensive processing	Lowest hunting; highest initial processing; intensive processing well represented
Site Types	Single and diverse activities equal percentage; moderate activity dominant; lowest diverse activity percent	Highest diverse activity percentage; single activities well represented	Only moderate and diverse activities; diverse activity dominant	Diverse and moderate activities equal; single activity sites present

butchering , hide processing, graver use) while evidence of intensive processing is completely absent. These sites were smaller overall, associated with low-to-moderate artifact diversity. This points to a population using individually provisioned toolkits and engaging in more focused tasks on the landscape, indicative of higher residential mobility.

There is no evidence for Early Holocene/Post-Mazama populations occupying the Walker Lake basin; however, Early-Middle Archaic populations began relegating their activities to lower elevations, with more time spent near the river than earlier groups. Formal tools continued to dominate artifacts during this time, while there is a noted uptick in primary reduction. Hunting activities continue to dominate sites and are combined with initial processing activities at ratios nearly identical to Paleoindian sites. The size of sites changes notably at the start of the Archaic. While single-activity sites continue to be important, in general, artifact diversity greatly increases. In fact, the Early-Middle Archaic has the highest overall percentage of diverse activity sites. These patterns suggest populations at this time continued to be highly mobile, residentially organized, and individually provisioned. At the same time, they were located lower on the landscape, used the landscape more broadly, and more intensively exploited local resources relative to earlier Paleoindian groups.

During the Late Archaic, landscape use was more focused near the river and the lake, with wash and upland use dramatically reduced. Formal-tool use continued to dominate sites relative to informal tools, with the highest overall percentage of these time-intensive tools relative to all age components. At the same time, primary reduction dropped, returning to levels present during the Paleoindian period. Hunting activities notably decreased during the Late Archaic, while intensive processing (e.g., seed grinding, use of fish-nets, wetland plant processing) entered the record, being slightly more common than initial processing. This change is associated with an increase in artifact diversity at sites. Single-activity site types are completely absent during this time, compared to a middling percentage of moderate-activity sites and a high percentage of diverse-activity sites. Overall, the patterns observed indicate an increase in landscape exploitation and perennial water-body use. While formal tools continued to be important, suggestive of individual provisioning, the increase in intensive processing associated with less transportable artifacts (i.e., ground stone), high site-activity counts, and increased lowland exploitation is suggestive of a less mobile population with some place provisioning. The decrease in upland use and single-activity sites, however, suggests limited logistical-landscape exploitation. Combined with the high number of formal tools and minimal evidence of primary-core reduction, it seems that Late Archaic populations were more likely to be residentially mobile when local resources became depleted.

Finally, during the Late Prehistoric, people were more focused on the lower elevations of the Walker Lake basin, primarily occupying the lake. The river appears to have been abandoned while uplands and washes continued to be exploited. At the same time, informal tool use and primary reduction increased, with the highest percentage of both tool production types occurring during this time. Hunting activities were further reduced relative to the Late Archaic, replaced with increased initial processing activities and continued intensive processing. The diversity of artifacts on sites remained high, moderate-activity and diverse-activity sites make up 90% of the assemblage. Single-use sites are present, however, suggesting logistical forays supported larger site occupations. Together, the results provide evidence of reduced individual provisioning with lower formal-tool presence, increased expedient-tool use, and high counts of less-portable tools such as ground stone. Sites tended to be located near the lake and relatively large. Here, populations intensively exploited local resources, and they were provisioned with toolstone materials and perhaps other upland resources. The overall pattern is one of low mobility and place provisioning strategies at base camps near the lake and logistical provisioning from uplands and washes.

Overall, landscape use in the Walker Lake basin from the earliest to latest age components shows a trend of increasing exploitation from ephemeral to perennial water features and a shift from higher to lower elevations. Populations also increasingly exploited resources, with sites trending towards higher artifact diversity, larger sizes, and increased processing activities. Over time, technological organization shows that formal tools were important from the Paleoindian period through the end of the Archaic. During the Late Prehistoric, this abruptly changed with more expedient tools and higher frequencies of core reduction. These results point to overall reduced mobility through time, and beginning with the Late Archaic, place provisioning, and eventually logistical support of longer-term base camps associated with Walker Lake.

4.5.1.2. Walker Lake Basin Landscapes

Statistical results summarized in Table 4.8 indicate a close correlation between landform type and elevation range across the Walker Lake basin. The lowest elevations, below the historic highstand tend to be associated with Walker Lake features as well as lower modern and relict Walker River channels. The middle elevations, between the historic and Sehoo highstands, are primarily associated with wash landforms, though there are a couple of upper river sites in this range. The upper elevations, above the Sehoo highstand, are exclusively associated with wash landforms. As a result, these elements can be discussed together to develop a broad view of how past populations used the Walker Lake basin. In fact, elevation may be considered proximal to landform types because the patterns observed for landform types appear to drive the signatures found across the elevation ranges.

Washes and upper elevations above the historic highstand tend to show evidence of low primary reduction and high formal-tool use. Hunting is the dominant activity associated with these landscapes, with low percentages of all processing activities. At the same time, sites tend to have minimal artifact diversity, with single-use site types being the overwhelming majority and steadily declining percentages of moderate and then diverse-use types. These patterns suggest high mobility and individual provisioning strategies associated with washes and upper elevations. There is no evidence for base camps or long-term occupations on this part of the landscape, and it is likely the people using washes and uplands were either residentially mobile or logistically oriented.

Table 4.8. Overview of landscape and artifact category observations by landscape areas.

	Walker Basin Landforms					
	Lake Sites	**River Sites**	**Wash Sites**	**Below Historic**	**Historic-Sehoo**	**Above Sehoo**
Reduction Activities	Highest core reduction	High secondary reduction	High secondary reduction	Highest core reduction	Lowest core reduction	Core reduction similar to low elevations
Tool Production	Lowest formal tools	Middling formal and informal tool distribution	Highest formal tools	Lowest formal tools	Highest formal tools	High formal tools near middle elevation range
Task Activities	Low hunting tasks; highest initial processing; middling intensive processing	Lowest hunting tasks; low initial processing; highest intensive processing	Highest hunting tasks; lowest processing tasks	Lowest hunting tasks; highest processing tasks	Highest hunting tasks; low processing tasks; nearly identical to upper elevation range	High hunting tasks and low processing tasks; nearly identical to middle elevation range
Site Types	Middling single activities; lowest moderate activities; highest diverse activities	Middling single activities; highest moderate activities; middling diverse activities	Highest single activities; middling percentage of moderate activities; lowest diverse activities	Moderate single activities; low moderate activities; highest diverse activities	Lowest single activities; moderate activity dominant; middling diverse activities	Highest single activities; low moderate activities; lowest diverse activities

There are two exceptions to the signature discussed above, both associated with difference between the highest elevations above the Sehoo highstand and the middle elevations between the historic and Sehoo highstands. Primary-reduction activities in the highest elevations are much more common than those noted in the middle elevations, approaching the percentage observed at the lowest elevations. Most toolstone in the local basins are found in uplands and are rarely present on the basin floors (Kelly 1988**,** 2001). Local obsidian sources are also found in the uplands, especially at Mt. Garfield east of Walker Lake (Giambastiani 2005). As such, it is likely that the higher percentage of primary reduction associated with the uplands is the result of logistical provisioning and *in situ* testing of toolstone material at sources. The second exception is the high artifact diversity occurring at middle elevations relative to upper elevations. Middle elevations have the lowest percentage of single-use sites and the highest percentage of moderate-use sites relative to other elevations. This implies more intensive resource exploitation within this elevation range, perhaps due to higher presence of perennial grasses (e.g., ricegrass) and other foraging resources that required more intensive landscape use and exploitation before they were brought to base camps (Zeanah 2004).

River sites generally show a pattern of technological organization and landscape use that falls between upland wash sites and lowland lake sites. They have minimal evidence of primary reduction and the percentage of formal tools is lower than washes but higher than lakes and lowlands. Site activities are split relatively evenly between hunting and intensive processing with a slightly lower percentage of initial processing. Artifact diversity is much greater than washes and the uplands, with fewer single-use sites and increased percentages of moderate and diverse-use sites. The overall signature at river sites is one of reduced individual provisioning, increased place provisioning, but limited logistical support. These sites are associated with extensive processing and resource exploitation, suggesting that people went here to forage and process valuable resources. Nonetheless, while they provisioned these locations with ground stone and materials required for processing tasks, they also seemed to bring their tools and materials with them and stayed for less time than at sites closer to Walker Lake.

Sites associated with Walker Lake and the lowest elevations have the highest percentage of primary reduction and informal tools. These sites have low overall-hunting activities and high-overall processing activities. While lake sites have a lower percentage of intensive processing activities than river sites, this is combined with the highest percentage of initial-processing materials of all landforms. Artifact diversity is also high for these sites, with the highest percentage of diverse-activity sites and numerous moderate-activity sites. Nonetheless, single-activity sites still dominate the record in these regions. Similar to river sites, there is strong evidence of reduced mobility, place provisioning, and logistical organization at low-elevation lake sites. The evidence for increased expedient-tool use and primary-reduction activities indicates these landscapes were logistically supported. Intensive-landscape exploitation and high-artifact diversity also suggests longer term stays and reduced mobility. Generally, it appears that this portion of the landscape was where base camps were primarily located within the Walker Lake basin.

The pattern of generally decreasing mobility and increased landscape exploitation from washes to the river to the lake and from higher-to-lower elevations is similar to the patterns observed for different age components. To understand their implication, it is important to consider them in the context of nearby archaeological signatures and general models for Great Basin landscape use.

4.5.2. The Walker Lake Basin, Nearby Sub-Basins, and Great Basin Land Use Models

4.5.2.1. Regional Archaeology

Patterns for mobility, technological organization and subsistence strategies across the Carson Desert, Mono Basin, Owens Valley, and Walker Lake basin all show generally decreasing residential mobility, increasing logistical organization, and more intensive landscape exploitation from earlier to later periods. How the Walker Lake basin record compares to these nearby basins helps to clarify how precontact populations exploited landscapes and lake basins across the western Great Basin.

Evidence for the earliest, Paleoindian (human entry-9,000 cal BP) occupations in all four basins indicates small groups with high-residential mobility (Adams et al. 2008; Bettinger 1999; Brady 2011). In the Walker Basin, these signatures are associated with focused activities in upland areas associated with ephemeral water or abandoned lake shorelines. In the other three basins, however, late Pleistocene and early Holocene sites are commonly associated with active shoreline features such as the edge of Owens Lake, the saline wetland near Mono Lake, and the high Carson Lake shoreline at the Sadmat site. In Owens Valley, early sites are found in multiple contexts, including more upland areas, similar to the Walker basin. The absence of lake exploitation in the Walker Lake basin may be due to low lake levels during the late Pleistocene and early-mid Holocene (Benson and Thompson 1987; Bradbury et al. 1989), meaning there was no shoreline to occupy. Conversely, Paleoindian groups may have occupied shorelines at extremely low lake elevations that have subsequently been buried by lacustrine sediments during higher lake levels (Puckett 2021).

During the Early Holocene/Post-Mazama period (9,000-5,000 cal BP), there is a general dearth of archaeology across the Great Basin due to increasingly hot and dry conditions (Grayson 2011; Hockett et al. 2013). This is certainly true of the Walker Lake basin where the lake continued to be exceptionally low or absent (Benson and Thompson 1987; Bradbury et al. 1989) and there are no sites dating to this period. Similarly, Kelly (1985, 2001) identified no sites dating before 5,000 cal BP in Carson Desert, and overall evidence suggests the region was minimally occupied. In both the Mono Lake wetlands and Owens Valley, sites occur at this time, but still they indicate a reduced human presence until 6,000-5,000 cal BP. It is likely that the inhospitable environment and low to dry lake meant that people avoided the Walker Lake basin across the Early Holocene/Post-Mazama. However, if a low, saline marsh existed here, it is possible populations occupied its shores and that these sites are buried under fine-grained lacustrine sediments underneath the modern lake’s waters.

For the Early-Middle Archaic (5,000-1,325 cal BP), the record in the Walker Lake basin is similar to the records across other western sub-basins. Here there is evidence for increased landscape exploitation, expanded reliance on lake and river resources, and reduced residential mobility relative to Paleoindians. Nonetheless, people appear to have remained quite mobile overall, relying on individual processing and broad landscape exploitation. Comparably, in the Carson Desert and Mono Lake wetlands there is evidence for broader marsh/wetland use and relatively high mobility associated with seasonal residences until 2,000-1,500 cal BP (Brady 2011; Kelly 2001; Zeanah et al. 1995). In Owens Valley resource exploitation also increased, but it was associated with evidence for reduced residential mobility as the number of house features increased along with evidence for shorter logistical forays (Eerkens 2012). The differences between the basins suggest that north of Owens Valley, high residential mobility was maintained during the Early-Middle Archaic while resource exploitation and landscape use broadened. In Owens Valley, however, populations seem to have begun to reduce their mobility patterns, requiring increased, shorter range, logistical support of base camps and residences (Brady 2011; Kelly 2001; Eerkens 2012).

During the Late Archaic (1,325-600 cal BP) there is evidence for further reduced mobility and expanded resource exploitation across multiple sub-basins. The Walker Lake basin record shows more artifact diversity, evidence of some logistical organization, high numbers of intensive processing artifacts, and landscape use focused at the low elevations around the lake and river. The other three basins show a similar pattern. Marsh habitations in the Carson Desert were occupied for multiple years but appear to have been abandoned when marshes dried and environmental productivity decreased (Kelly 2001). At the same time, Owens Valley populations further reduced their logistical range and residences became smaller, suggesting less intergroup cooperation (Eerkens and Spurlin 2008). At Mono Valley, landscape use became focused on freshwater wetlands and mobility dramatically dropped (Brady 2011). Just before this period, however, from 1,500-1,350 cal BP people at Mono Lake *expanded* their mobility and reduced their landscape exploitation, returning their focus to brackish wetlands (Brady 2011).

Across the Late Prehistoric (600 cal BP to contact), the trends observed during the Late Archaic continued or expanded in the sub-basins. Walker Lake basin landscape use became focused on the lake at lower elevations while river use was abandoned. Site-artifact diversity increased with larger site sizes around the lake and evidence for logistical support and landscape provisioning from the uplands. At the same time, the records in the Mono Basin and Owens Valley indicate a continuation or expansion of the patterns observed during the Late Archaic (Brady 2011; Eerkens 2012). In the Owens Valley, this is combined with broader landscape use and an expanded trade network (Eerkens 2012). The Carson Desert record presents difficulties. Kelly (2001) proposes that the patterns observed after 1,500 cal BP may have continued, with more residential stability. However, he also suggests that residential mobility may have increased as people were more willing to abandon residences near the marsh in pursuit of other resources across the region. Landscape-use models focused on residential locations suggest that populations were moving across the Carson Desert in response to women's activities focused on high-production resource patches (Raven and Elston 1988; Raven 1990; Zeanah 2004; Zeanah et al. 1995). In response, men moved their hunting patches to different regions or turned their attention to foraging for plant-based resources or smaller game closer to the residential camps (Zeanah 2004).

In general, the patterns observed in the Walker Lake basin compare favorably to those found in nearby sub-basins. Nonetheless, there are notable exceptions. Paleoindian populations may have used the Walker Lake basin exclusively in the uplands, a unique adaptation compared to the lacustrine focused adaptations found in other basins. The Walker Basin may have been completely abandoned after 9,000 cal BP, similar to the record in the Caron Sink, but more extreme than the Mono Basin and Owens Valley. Both of these periods, however, may have seen Walker Lake used at low elevations next to saline marsh environments that are now underwater and deeply buried. From the Early Archaic through the Late Prehistoric period, the Walker Basin follows the general trend of the other regions: reduced residential mobility, increased landscape exploitation, and expanded logistical organization. The Walker record, however, suggests that mobility may have been higher relative to other sub-basins where large camps and more intensive landscape exploitation appears to have occurred, especially in the Carson Desert and Owens Valley. Interestingly, during the Late Prehistoric Walker Lake basin populations may have continued to decrease their mobility and intensify landscape exploitation while Carson Desert groups were expanding their mobility and diversifying their landscape use. Perhaps Walker Lake provided abundant resources encouraging intensive lake occupations while the Carson Desert provided a variety of different resources encouraging movement between patches (Kelly 2001).

Lastly, archaeology in the Walker Lake basin does little to address models for prestige hunting or the construction and use of communal hunting features (Hockett et al. 2013; McGuire and Hildebrandt 2005). While there is evidence of upland use and focused, single-activity hunting sites beginning with the Early-Middle Archaic, there is little to associate these sites specifically with men's hunting forays or selective pressures directing mate choice. At the same time, none of the sites identified in the basin can be defined as a communal hunting feature. It is possible that evidence for prestige hunting or communal hunting exists at upper elevations within the Walker Lake basin that were not investigated as part of this research. In fact, one site recorded in 2015 (Walk-01) was associated with multiple hunting blinds and a scatter of broken projectile points and bifaces; however, Hockett et al. (2013) clarify that hunting blinds do not indicate communal hunting. Conversely, there were numerous cairns observed at Walk-01 and along the Sehoo shoreline feature east of Walker Lake. The shoreline, consisting of a steep talus slope below a level bench, could have acted as a natural "fence" forcing game between the lake and the mountains as they migrated north-south along the Walker Lake boundary. As such, these cairns may be indicative of communal hunting or associated activities (Bryan Hockett personal communication 2016). Considering the proximity between Walker Lake and the concentration of western Great Basin trapping features, it is likely that some features exist in the Gillis Range or other nearby areas and have yet to be identified.

4.5.2.2. Great Basin Landscape Use Models

The evidence for Paleoindian use of the Walker Lake basin is notably different from the record found in other western basins. Paleoindian sites in other sub-basins in western Nevada and southeastern Oregon are often associated with pluvial lake shorelines and wetland features (Adams et al. 2008; Smith 2010). At Walker Lake, these sites are limited to the uplands, wash features, and lake features that were far higher than the lake when they were occupied (Benson and Thompson 1987; Bradbury et al. 1989). This pattern provides evidence supporting the mobile-forager model over the tethered-wetland model, at least in the Walker basin. As noted above, if a saline marsh or low lake existed in the basin during Paleoindian periods, it is possible that shorelines may have been occupied that are now buried below deep-water lacustrine sediments underneath the modern lake. Without this evidence, however, it appears that people using the Walker Lake basin during Paleoindian times did so without focusing on lacustrine or marsh resources, suggesting the region provided valuable upland resources for highly mobile foragers moving between wetland resource patches outside the Walker Lake Basin (Jones and Beck 1999).

From the Early Archaic to the Late Prehistoric, the patterns of mobility and landscape use in the Walker Lake basin provide a useful case study for comparing the limnosedentism/limnomobile and the traveler/processor models (Bettinger and Baumhoff 1982, 1983; Heizer 1967; Thomas 1985). If these two models are interpreted as extremes along a continuum rather than dichotomies, then the record from 5,000 cal BP onward suggests a gradual transition from populations that were more limnomobile and traveler oriented to those that were more limnosedentary and processor focused. Archaeology from the Early-Middle Archaic is indicative of groups that were residentially mobile and occupied a diverse range of environments while exploiting many resources including those from wetlands. Over time, the intensity of resource processing increased in conjunction with longer, more extensive occupations of river and lake features. These later populations logistically supported lower base camps with upland resources such as toolstone, large game, and perennial grasses. One valuable trend to note is that the gradual transition from more traveler-oriented to more processor-oriented populations across 5,000 years suggests that this change occurred *in situ* and was the result of localized adaptations. The lack of a clear transition at 1,500-600 cal BP and instead a pattern of gradual change contradicts models for sudden population replacement by Numic-speaking groups in the latest Holocene, bringing with them more processor-oriented adaptations and ultimately out-competing the local traveler-oriented groups (cf. Bettinger 1994; Bettinger and Baumhoff 1982, 1983).

4.5.3. The Walker Lake Basin Archaeological and Environmental Record

The local environmental record for the Walker Lake basin has important implications for predicting the resources available for people living in the region, understanding the archaeological record, and comparing the record to that in the Carson Sink. Further, the models and observations above concerning landscape use, mobility, and subsistence strategies should be compared to changes to Walker Lake and Walker River for modeling expectations related to overall environmental productivity.

The presence of a low lake or dry playa in the Walker Lake basin from 15,000-5,000 cal BP, resulting from the drainage of the Walker River into the Carson basin, minimized the availability of resources in the region, especially those associated with wetlands or lakes. As such, it would be expected that local populations would have been low during this time. If a low, saline lake or marsh were present, then people may have used it similarly to the saline and brackish wetlands in the Mono Basin (Brady 2011). Models suggest that part of the reason the lake was so low was that Walker River flowed north into Carson Sink. As such, it would be expected that people would be more likely to occupy the Carson Desert and take advantage of the resources this added water flow provided. The Walker Lake basin record supports this model. Paleoindian sites are restricted to upland washes and lake shoreline features that would have provided good viewshed. Further, there are no sites dating to the Early Holocene/Post Mazama period, perhaps suggesting the basin was exceptionally dry at this time. The use of a low, saline marsh or shallow lake is not present in the record, but again, these sites would now be underwater and well buried (Puckett 2021).

During the mid-Holocene, Walker Lake transgressed and Walker River was flowing into the basin. This is associated with the renewed presence of archaeology in the basin by 5,000 cal BP. Sites appear along the river and the lake at this time, suggesting both provided valuable resources. Additionally, there is evidence for more intensive resource exploitation and wide landscape use, suggesting a broad range of valuable resources across the region.

The Early-Middle Archaic (5,000-1,325 cal BP) saw two major lake recessions, from 2,500-2,000 cal BP and after 1,500 cal BP. Unfortunately, the temporal resolution of the archaeological record is not fine enough to determine if landscape use or behavioral adaptations changed during these dry periods. If these periods were associated with river diversion to the north into Carson Sink (i.e., Adams and Rhodes 2019b), then people may have limited their use of the Walker Lake basin at this time, focusing more on upland resources or moving into the Carson Desert. Conversely, if Walker River split, flowing partly into Walker Lake, then Walker Lake basin resource use may have continued with minor shifts across the landscape, focusing more intensively along the river and lower lake elevations.

The presence of a reduced, but flowing, Walker River is evident during the Late Archaic. Lake-level models suggest Walker Lake was low at ~1,250 and 860 cal BP, separated by a highstand at 1,000 (Adams and Rhodes 2019b). Puckett (2021), however, suggests that lake level may have remained around 1212 masl or lower across this time span due to reduced river flow from 1,325-750 cal BP. The archaeological record during the Late Archaic is dominated by river and lower lake landscape use, suggesting that partial river flow was the prevailing condition. At the same time, the reduced presence of Late Archaic sites, especially those with a single component (n = 3), may indicate that Walker Lake basin landscape use and occupation was reduced due to low lake levels and lower overall environmental productivity.

After 750 cal BP, Walker Lake generally remained high, with a single recession at 300 cal BP that did not get as low as the 860 cal BP recession. This correlates well with the decreased residential mobility and increased lake use and resource exploitation during the Late Prehistoric. High-resolution studies may show a reduction in occupation or population between 650-300 cal BP, but since the lake level does not appear to have fallen below 1,210 masl, its average elevation from ~1325-860 cal BP, the region may have seen similar or higher occupation than was present during the Late Archaic.

The correlation between the archaeological record, environment, and lake levels in the Walker Lake basin shows a strong relationship between how people used the basin and local environmental changes. Unfortunately, the resolution of lake-level research is much higher than the archaeological record, meaning that short term changes in landscape use and occupation in response to local environmental changes are not currently visible in the record. This shows that site excavations and broader landscape research across the Walker Lake basin would be invaluable for better understanding the relationship between people and their environment.

4.6. Conclusion

The results from this study reject the null hypothesis and support both alternative hypotheses. Populations used the Walker Lake basin differently at different times (H_1) and the landscape was an important factor for how people behaved at different locations (H_2). Further, the nature of the different types of landscapes used over time and across space provide valuable evidence for technological organization and mobility within the Walker Lake basin.

Similar to the record in nearby sub-basins, investigations into the use of the Walker Lake basin showed an overall decrease in residential mobility and an increase in place provisioning through time. The uptick in place provisioning during the latest periods combined the use of base camps with logistical forays. There is also evidence for increasingly intensive resource acquisition over time, as later populations engaged in more intensive processing activities.

While these results generally align with the observations from other western sub-basins, there are important differences. The Walker Lake basin shows a unique focus on upland resource during the Paleoindian period, likely due to limited resources and low lake levels. It also shows less evidence for residences or large-scale base camps, suggesting it did not support the level of sedentism present in the Carson Desert or Owens Valley. Further, during the Late Prehistoric, while the Carson Desert record appears to show increased residential mobility, the Walker Lake basin shows evidence for the lowest levels of mobility within the basin. This may have been caused by reduced resource variety and a reliance on lake resources such as Cui-Ui and Cutthroat trout, compared to relatively higher resource variability in the Carson Desert.

Overall, the Walker record provides some evidence for the mobile-forager model for Paleoindian landscape use. From the Early Archaic to the Late Prehistoric, landscape use, mobility, and subsistence strategies suggests a gradual transition from more limnomobile and traveler-oriented adaptations to a more limnosedentary and processor-oriented approach. On the other hand, there is little evidence to address localized models for landscape use such prestige hunting and costly signaling or the construction and use of communal hunting structures such as corrals and fences.

The environmental and lake record in the Walker Lake basin generally aligns with associated expectations in the archaeological record. Paleoindian populations are sparse and Early Holocene/Post-Mazama occupations are absent, as would be expected if the lake was a dry playa or a low, hyper-saline marsh. The return of the lake after 5,000 cal BP is associated with an abrupt increase in archaeological materials and increasingly intensive resource exploitations. It is likely these behaviors were associated with longer, more extensive use of resource patches in the Walker Lake basin (Zeanah et al. 1995; Zeanah 2004), resulting from a larger, more stable Walker Lake from the middle to late Holocene. Unfortunately, the possibility of low elevation lake or marsh use has not been identified from any period as these sites would be deeply buried below the modern waterline. Further, the resolution of the lake and environmental record is finer than the archaeological record, so the relationship between precontact landscape use and environmental change remains uncertain across much of the late Holocene.

An important area for further investigation is the relationships between age and site types. The high mean rank for activity counts during the Early-Middle Archaic is associated with provisioning individuals and a more residentially-organized mobility signature while the low mean rank of activity counts during the Late Prehistoric is associated with place provisioning and a logistically-organized mobility signature. These results counter expectations for the number of activities performed on sites and the types and levels of mobility practiced by site inhabitants. Another area for expanded research is between the archaeological and environmental records. The low resolution of site ages across the region limits associations between age components and changing environment and lake levels. Additional investigations in the Walker Lake basin focused on chronology building will help to clarify these issues.

This study provides valuable evidence supporting expectations and previous hypotheses for the Walker Lake basin (Rhode 1987). The largest sites associated with the most activities and time intensive resource processing tasks are associated with perennial water features below the Sehoo highstand: Walker Lake and Walker River. It is here that people in the Walker Lake basin made their base camps, provisioned the landscape with toolstone and upland resource, made extensive use of expedient tools, and processed the various faunal and floral resources either brought to camps or found nearby. Interestingly, more-than-expected, resource-intensive-processing activities occurred near the river, while at the same time, river sites have less tool diversity and a less robust place-provisioning signature than lake sites. This suggests that the river was the source of specific plant or other resources requiring intensive processing, but these sites were less intensively occupied or were less likely to be used as base camps. This may be indicative of a more residentially mobile strategy as populations made use of a wider range of resources similar to the model proposed by Kelly (2001). It is also apparent that the uplands were used primarily for resource procurement associated with small mobile groups. During earlier periods, these were more residentially-organized populations, while during the Late Archaic and Late Prehistoric, upland resources were probably acquired during small-group, logistical forays supported by nearby base camps.

This paper helps to better define the broader patterns of land use in the Great Basin and provide additional evidence for human behavioral adaptations. Importantly, they show that past populations organized their mobility and technological provisioning around the landscape. Specifically, people appear to have based their activities around Walker Lake, Walker River, and washes rather than by elevation. While the results have been compared with other basins from a temporal perspective, applying a similar landscape perspective, tying sites to water features in the Carson Desert, Owens Valley, Mono Basin, or other sub-basins will help reveal variations in landscape use across the region.

Often discussions about landscape adaptations are organized around specific periods or cultures, but this investigation suggests that landscape parameters may in fact strongly influence technological organization within a given culture's overall mobility strategy. As a result, unless both time and landform are controlled for, conclusions about technological organization for a given period or culture may be artificially skewed by site distributions and the nature of the landscapes investigated. To address this problem, this study investigates both landscape and time, showing that the landform a site is found on strongly correlates to signatures indicative of mobility, technological organization, and subsistence strategies. This correlation presents a challenge in the Great Basin when archaeological research focuses on specific landforms such as beach ridges, marshes, rockshelters, or caves. Broad models of landscape use and mobility focused on single landforms are likely to miss the full range of activities carried out across a landscape during a given period (Kelly 2001; Thomas 2014b; Thomas et al. 1983, 1988). My results highlight the range of adaptive approaches that were adopted across both time and space in the Walker Lake basin, helping to define the full range of technological adaptations, mobility, and subsistence strategies.

5. CONCLUSIONS

This dissertation discusses new research and analyses in the Walker Lake basin to better understand the archaeological, climatic, and environmental record. It is focused on three broad but interconnected topics: 1) multi-methodological approaches to research that allow for more complete data collection and broader climatic, environmental, and archaeological models; 2) regional geomorphological and environmental analyses designed to better understand the history of the Walker Lake basin; and 3) statistical analyses of precontact archaeological sites to understand the relationship between behavioral adaptations and the landscape. Each topic was investigated in one of the sections, allowing for an in-depth discussion of the research.

Section 2 provided an overview of the methods and results from fieldwork to highlight the effectiveness of combining underwater and terrestrial research. These methods allow researchers to collect a broad range of data, target untapped sources of information, and generally investigate regional histories. Section 3 detailed the geomorphological and environmental components of the study, providing an overview of the sub-bottom acoustic, underwater excavation, upland cutbank, and tephra datasets. These data provide new information about the history and timing of Walker Lake level changes and the local environment. The results and mechanisms for lake change were then discussed in the context of broader environmental changes across the west-central Great Basin. Finally, Section 4 addressed the Walker Lake basin archaeological record, providing an overview of recorded sites and their associated artifacts to identify the relationship between human behaviors and the landscape. Using a series of statistical tests, analyses showed a close relationship between age, landscape, and technological adaptations across the Walker Lake basin. These show general correlation with other nearby sub-basins, as well as minor differences that may be indicative of the unique hydrological situation created by Walker Lake and Walker River with respect to environmental changes, river flow directions, and lake levels.

The integration of these research efforts is rooted in the relationship between the environment and human adaptations. The importance of Walker Lake to local environmental productivity requires an in-depth understanding of the history of the lake to interpret how environment correlates to the archaeological record. Similarly, the unstable nature of Walker Lake requires archaeological and geomorphological research to include lake and river features both above and below the contemporary waterline. The result is a wholistic approach to geomorphological and archaeological research both in the field and in the laboratory that expands upon and integrates various Walker Lake records. This then provides a robust study of regional environmental and archaeological change that can be effectively integrated into our broader understandings of the west-central Great Basin.

5.1. Combining Underwater and Terrestrial Research in the Walker Lake Basin

By combining underwater and terrestrial methodologies to better understand the Walker Lake basin record, I developed a research program of mutually supportive methods that resulted in more data collection and better results. On land I directed archaeological walk-over survey, site recording, cutbank survey, and auger excavation near the north end of Walker Lake. Underwater, I performed swim-over scuba survey, acoustic sub-bottom survey, underwater test excavation, and coring. Combined, these methods allowed for more effective data-collection. The terrestrial work allowed for continuous data-collection when weather or equipment issues limited underwater fieldwork. At the same time, the large field crews required for underwater research meant that terrestrial survey and data recording had the benefit of more personnel.

The combined approaches produced invaluable information about the Walker Lake basin archaeology and environmental history. The terrestrial walk-over survey identified 38 new precontact archaeological sites from Paleoindian, Archaic, and Late Prehistoric periods. During cutbank survey we recorded a number of stratigraphic profiles, eight of which provided important information for contextualizing environmental and lake-level changes at lower elevations. We also identified and sampled the North Mono tephra marker horizon in the cutbanks, providing a temporal marker in sediment profiles across the basin. A second, lower tephra deposit observed in cutbank 7 provided evidence for the earlier South Mono Eruption, helping to further clarify the context of Walker Lake basin environmental proxy records. The auger excavation allowed for associations between the cutbank record and the underwater excavations, demonstrating continuity above and below the waterline.

Underwater work was novel for the Walker Lake basin and the Great Basin in general, and each aspect of this research produced positive results. The initial swim-over survey identified a shoreline feature in 4-4.7 meters of water. This demonstrated the potential for terrestrial features to be preserved within the lake. The sub-bottom survey profiles showed a rising sand deposit likely indicative of a transgressive lake phase gradually covering the lowstand deltaic deposits in the northern half of Walker Lake (Feature 1). Sub-bottom data also showed two buried river channel features as well as evidence for preserved rivulet features and deeply buried stratigraphy that may be indicative of early-to-mid Holocene lake levels. Underwater test excavation and coring of Feature 1 and Feature 3 recovered medium to coarse sands indicating high-energy deposition in a littoral or shallow-water environment. Organics from these sands produced dates at ~2,250 cal BP for Feature 1 and between 950-700 cal BP for sands near Feature 3. These dates are associated lowstand events that deposited sands in a littoral environment, providing strong evidence for previous lake lowstand elevations.

This work produced invaluable information for reanalyzing the Walker Lake basin environmental and geomorphological record and improving our understanding of regional archaeology. Initial observations of the distribution of archaeology sites across the Walker Lake basin suggest that Paleoindian populations primarily focused on lake shoreline features and the uplands. During the Early, Middle, and Late Archaic, populations appear to be located near the river channel and washes within the Walker Lake basin. Wash use appears to have decreased during the Late Archaic, as populations focused more on lower elevations and the lake. During the Late Prehistoric, populations focused on the lake, but only above 1,235 masl. These sites are rarely found at the lowest elevations investigated. There is also some evidence of higher elevation use during the Late Prehistoric, perhaps while using the upper Walker River or sending logistical forays into the uplands. Section 4 investigated these trends with in-depth statistical analyses looking at site locations, artifact distributions, and other technological variables.

Combined, the results of my fieldwork in the Walker Lake basin demonstrate the importance of using both underwater and terrestrial approaches. Underwater research showed that perennial lakes within the Great Basin are valuable sources of environmental information. This information can be used to contextualize the archaeological record and identify relationships between behavioral adaptations and local environmental changes. Further, 35 of the 38 newly identified sites in the Walker Lake basin would have been underwater as little as 130 years ago. Artifacts from these sites can be temporally correlated to the Paleoindian, Early, Middle, and Late Archaic, and Late Prehistoric periods. The fact that these sites were preserved despite being underwater for extended periods of time highlights the likelihood that similar sites are preserved within Walker Lake. Terrestrially, much of the Walker Lake basin remains uninvestigated. Broader survey across the landscape combined with site excavation is likely to reveal important details about the local archaeology. Additional dating and tephra analyses from cutbanks and analyses of abandoned river channels can provide important details about the timing of lake level and environmental changes in the basin.

Overall, efforts combining underwater and terrestrial approaches in the Walker Lake basin were successful, and they provide a useful example for future Great Basin research programs. More importantly, the approaches were essential for developing an integrated understanding of the environmental and archaeological record of the Walker Lake basin. By including a broad suite of methods and proxy records, the resulting dataset allows the environmental and archaeological records to be compared and investigated across myriad cultural and lake changes over the last 15,000 years.

5.2. Terrestrial and Underwater Investigations of the Geomorphological and Environmental History of the Walker Lake Basin, Nevada

Research addressing the changes in lake level and environment in the Walker Lake basin focused on three goals: 1) identifying the presence of preserved lacustrine and fluvial features buried under Walker Lake, 2) using new proxy and environmental records to update the Walker Lake level curve during the Holocene, and 3) using new proxy record data and geomorphological analyses to better understand the environmental history of the basin during the late Holocene. As Section 2 illustrated, these goals were accomplished by combining terrestrial and underwater research approaches.

Sub-bottom profiling and the subsequent underwater test excavations and coring provided clear evidence for preserved lacustrine and fluvial features underneath Walker Lake. The sub-bottom profiles identified three clear buried landforms within the stratigraphic data. Feature 1 consists of two horizontal sand deposits that appear to be draped across a prograding delta forming where the river meets the lake. These sands appear to represent littoral or shallow-water sand deposition during lake lowstands. The sands were most likely deposited as lake levels gradually rose across the existing deltaic deposits during lake transgression, after which they were buried in fine-grained deep-water sediments. East of Feature 1, Features 2 and 3 provide evidence for fluvial downcutting in the lower basin during lake lowstand events. Feature 3 is a notable landform represented by a clear dip in the stratigraphic profile capped by a less pronounced sand deposit. Feature 2 represents less fluvial downcutting than Feature 3, but it appears across all transects at a consistent easting. In addition to these landforms, the sub-bottom profiles provided some evidence for the preservation of more ephemeral fluvial events and deeply buried fluvial or high-energy lacustrine features below Features 1, 2, and 3.

Underwater testing of the sediments associated with Feature 1 and Feature 3 demonstrated the presence of the sand deposits identified as Reflection 1 and predicted to be associated with these features. Organic materials were collected for radiocarbon dating, cores were sampled and analyzed to profile and categorize the submerged sediment profile, and paleoecological materials were counted to better understand the associated environments. Through these efforts I successfully accomplished my first research goal and demonstrated the presence of preserved underwater features and landforms capable of providing important information about Walker Lake basin environmental and lake history.

Using the information from the underwater test excavations, cores, radiocarbon samples, tephra analyses, and cutbank observations from the Walker River channel, this study reevaluated the late Holocene Walker Lake level curve presented by Adams and Rhodes (2019b). The earliest adjustment to the curve was applied to the lake lowstand dating between 2,500-2,000 cal BP. A fish bone collected from the TB-1 cores provided a date of 2,250 cal BP in a high-energy sand package with a lower elevation of ~1,178 masl. This indicates that the bone was deposited in a littoral or shallow water environment during low lake levels. This date provides the first estimate for lake level (1,178 masl) during this lowstand. The second adjustment is associated with the South Mono Eruption dating to 1,325 cal BP. A tephra associated with this eruption was observed in the lower portion of cutbank 7, deposited in a fine loamy sand. The sediment associated with this tephra indicates that it was deposited in a higher-energy, shallow water context that Adams (2007) identified as <5 meters below the water surface. Since this tephra is at an elevation of 1,203.7 masl, lake level was estimated at a level at ~1,208.7 masl during a recession event coinciding with the South Mono Eruption.

When comparing the previous historic lake level curve (Adams and Rhodes 2019b) to the new results, it is apparent that a proposed highstand at 960 cal BP is an outlier and should be rejected. Instead, lake level likely stayed between 1,205-1,212 masl between 1,325-860 cal BP when a dramatic drop in lake level occurred. This drop in lake level elevation is based on radiocarbon dates collected from the TB-2 and TB-3 cores. All but one of these dates were collected from high-energy, shallow-water sands indicative of a littoral or near shore environment. They point to a lake recession at 1,180 masl or lower between 860-750 cal BP. Lake level rapidly rose after this event, and by 750 cal BP it was above 1,185 masl, depositing sandy clays during transgression.

The final adjustment to the lake curve is based on the location of the North Mono tephra in sediment profiles from across the Walker Lake basin. This tephra is deposited in low-energy, deep-water sedimentary contexts in the underwater excavations, the auger, and in cutbanks 5 and 7. In cutbanks 2 and 3, however, the tephra material is not exclusively in fine-grained sediment packages. In these cutbanks the tephra is found in both fine-grained low-energy sediments and high-energy fine sand/loamy fine sand. We argue that the lake was slightly above the cutbank 2 elevation of 1,230 masl during the North Mono Eruption at 650 cal BP.

These results were compared to other environmental and lake records from the western Great Basin to address the mechanisms of lake level change in the Walker Lake basin from 2,500-650 cal BP. In general, it appears that both environment and river direction contributed to changing lake levels. Dryer climate conditions during the late Holocene dry period likely resulted in low lake levels across the Great Basin, including Walker Lake from 2,500-2,000 cal BP. Wetter conditions prevailed until the MCA at 1,100 cal BP, but Walker River flow split between Carson Sink to the north and Walker Lake to the south likely resulted in a lake elevation between 1,212-1,205 masl from 1,325-860 cal BP. A sudden increase in moisture in the upper Walker River watershed beginning at 878 cal BP downcut the river channel in Mason Valley, resulting in the river flowing exclusively into Carson Sink and an extreme lowstand in Walker Lake at 800 cal BP. Walker River began flowing back into Walker Lake by 750 cal BP, resulting in a highstand at 700 cal BP between 1,224-1,252 masl, perhaps near the 650 cal BP lake level at 1,235 masl.

To accomplish the final research goal, stratigraphic sequences of the Walker River cutbanks and the relative amount of floral and faunal materials in the underwater excavation blocks were reviewed. These data allowed for a comparison of lake-level stability across the lower portion of the Walker Lake basin and a review of environmental productivity during the last millennium.

Comparisons of the Walker Lake basin cutbanks point to a pattern of increasing lake-level instability as elevation decreases. The upper cutbanks, 1 and 2, have the lowest number of coarse-to-fine sediment-package transitions. This indicates that for these cubanks, there is less evidence of depositional environments changing from high-to-low energy. Since the high-energy deposits observed in the cutbanks consist of shallow-water or littoral sands, this indicates that the highest cutbanks record the fewest number of lake-level changes from shallow water to deep water. The number of transitions steadily increases with lower elevations, demonstrating a relatively complex series of coarse-to-fine grained sediment-package transitions below 1,212 masl. In particular, cutbanks 4-6 at an elevation of 1,211.2-1,210.1 masl have especially complex stratigraphy, suggesting this may be an unstable area of the Walker Lake basin with respect to lake level. I argue that this instability is likely due the presence of Pelican point to the west and an alluvial fan bulge to the east. These landforms create a bottleneck in the basin allowing relatively smaller changes in water volume to result in more noticeable changes to lake level. Below 1,210.1 masl, the number of coarse-to-fine sediment-package transitions remain high until 1,194 masl, the elevation of the auger. At this elevation lake levels became notably more stable relative to the number of coarse-to-fine transitions in the stratigraphic profile.

Finally, organic materials recovered during excavations point to changing floral and faunal productivity within the Walker Lake basin. The upper 1-2 levels of each excavation block had notably low fish bone counts, likely indicative of the current absence of fish in the lake. Small peaks in fish bone correlate to relatively flat flora counts in levels 3-4, perhaps indicative of artificial fish stocking in the lake. In TB-1, fish bone count increases in levels 12, 14, and 17 likely correlate to the historically higher lake levels. Level 17 may mark the lake highstand at 1868 as it also has high flora counts, indicating an especially productive lake basin. In TB-2 and TB-3, this same event may correlate to Levels 5-7 and Levels 8-10 respectively as both correspond to increases in flora and fauna counts. Below level 17, TB-1 appears to return to a low lake signature with relatively low flora and fauna counts. In TB-2 and TB-3, there are high spikes in flora and fauna counts affiliated with levels containing the North Mono Tephra. This likely corresponds to mass fish and plant die-offs resulting from the negative effects of the eruption. In general, organic materials show a relationship between fish and plant productivity in the Walker Lake basin as counts tend to increase in both at the same levels. There is also evidence for increased Walker Lake basin environmental productivity during higher lake levels.

Overall, this study of Walker Lake basin geomorphology and environmental history identified important areas for continued research, valuable proxy and stratigraphic records for revealing lake and environmental history, and new data for refining these histories. More broadly, the results provide invaluable details about the basin that can be used to better understand the correlation between environment and human behaviors. This is important because without high-resolution models of environmental and climate history, it is difficult to effectively compare human adaptations to the environment. Further, by integrating proxy records from above and below the contemporary waterline, this research included information from environments associated with high, moderate, and extremely low lake levels. This provides essential data needed to integrate the environmental and archaeological records while identifying important low-elevation, buried landscapes where humans could have lived. The refinement of the environmental and climatic record provided by this study is invaluable for interpreting regional archaeology and for investigating the human-environment relationship.

5.3. Landscape Adaptations Across the Walker Lake Basin, Nevada: A Statistically Grounded Investigation

Archaeological research in the Walker Lake basin used the entire known precontact site record to address two research questions. First, did past populations differentially use and exploit the landscape at different time periods? Second, did past populations, irrespective of time, organize their mobility, behavioral adaptations, and associated technologies differently based on their location on the landscape? This record was further used to determine if the Walker Lake basin corresponds to nearby archaeological signatures and to local environmental changes. This study used the distribution of sites and artifacts across the Walker Lake basin relative to age and location to address these questions. By investigating these data using a series of statistical tests I identified important patterns of landscape use across time and space that help to clarify the human-environment relationship in the western Great Basin.

My analyses show significant differences in site and artifact distributions relative to time. Paleoindian populations showed a pattern of high mobility with limited landscape exploitation. Their sites were primarily associated with upper lake features such as the Sehoo shoreline and upper wash landforms. This was combined with a technological signature focused on formal tool use, minimal core reduction, and few processing implements. These groups appear to have moved regularly between hunting patches while Walker Lake was low and the Walker River flowed into the Carson Sink. During the Early-Middle Archaic, site distributions on the landscape became more diverse, with more sites associated with the Walker River. Tool technologies remained organized around formal tools and secondary reduction, but the number of tool classes on sites increased, indicating more intensive site use. These data point to populations maintaining a residentially organized mobility strategy, but with increased landscape exploitation across a broader area. The change may have in part been driven by the return of a high Walker Lake and a perennial river during the Early-Middle Archaic.

Late Archaic populations were primarily focused on river exploitation, and sites tended to be located at lower elevations. These site distributions were associated with evidence of increased processing tool use (e.g., ground stone, informal tools, drills, etc.) indicating reduced mobility and increased place provisioning. The lake became relatively more stable during this period with fewer major lake recessions that lasted for shorter periods. Finally, during the Late Prehistoric, sites were primarily distributed at or near the lake with some sites scattered across the uplands, near washes. Sites near the lake showed evidence of high artifact diversity, abundant intensive processing activities, and place provisioning. Upland sites, on the other hand, tended to have low artifact diversity and were associated with individually provisioned toolkits. The patterns suggest that during the Late Prehistoric, populations had low mobility and used logistical forays to bring resources back to the camps near the lake. Overall, these results indicated that people used the Walker Lake basin landscape differently at different times, and that these differences may have been driven, in part, by changes to Walker Lake and Walker River.

When looking at the distribution of artifacts across the Walker Lake basin irrespective of time, the data provide a robust picture of differential landscape use based on landform locations and elevations. In general, sites at the lowest elevations near Walker Lake were larger with a greater diversity of tool classes. The artifacts on the sites tended to be associated with more primary reduction and initial processing tasks (e.g., cores, flake tools, scrapers, etc.). This points to the lake and lower elevations supporting reduced mobility and place provisioning at base camp locations. Sites associated with the river were also at lower elevations and had a high number of activities. These locations, however, had an increased presence of formal tools and artifacts associated with intensive processing tasks, along with a lower presence of primary reduction materials. These sites may have represented single-family or single-season camps where people engaged in focused resource exploitation. Conversely, sites near the lake were likely multi-family or multi-season camps where groups adopted a more generalized and intensive approach to landscape use. Finally, upland sites associated with washes had a distinct signature from lower river and lake sites. These locations were consistently associated with formal tools, hunting tasks, and fewer activities. People using the uplands were highly mobile, practicing individual provisioning strategies. During the earlier periods of occupation in the Walker Lake basin, this landscape was likely associated with residentially mobile groups, whereas later populations likely used the uplands for logistical forays. Combined, the data for landscape use in the Walker Lake basin provide strong evidence for differential landscape use in which behaviors and adaptations were directly tied to where people were located on the landscape.

Compared to the regional archaeological record, the Walker Lake basin follows the broader trend of reduced mobility, increasingly intensive local landscape exploitation, and greater use of lower-elevation wetland resources from earlier to later periods. Nonetheless, notable exceptions are present. In the Walker Basin Paleoindian sites are focused on upland resources, contradicting the record from other basins where these sites are generally associated with lake shoreline features and wetland resource use. During the Late Archaic and Late Prehistoric, the Walker Lake basin record shows the lowest levels of residential mobility, more intensive wetland exploitation, and evidence for place provisioning. In the Carson Desert, however, there is evidence for increased mobility and broader resource use. These differences are likely the result of localized conditions in the Walker Lake basin, such as low lake levels during the Paleoindian period and narrower resource availability after 1,500 cal BP (Benson and Thompson 1987; Kelly 2001).

The Walker Basin record suggests a general pattern of mobile forager landscape use during the Paleoindian period. From the Early Holocene to the Late Prehistoric, the trend is from more limnomobile and traveler-oriented populations to more limnosedentary and processor-oriented groups. There is little evidence for Numic population replacement as this change occurs gradually, and there is no evidence for a sudden shift in mobility and technological organization. Comparisons between the archaeological record and environmental change in the Walker Lake basin suggest that the low number of archaeology sites before 5,000 cal BP most of which were focused on upland-wash resources use, was related to to the fact that the lake was either a dry playa or hyper-saline marsh at this time. After 5,000 cal BP, the return of the lake and river is correlated with a broader, more robust archaeological record. Further, lake levels at or below 1,212 masl during 2,500-2000 and 1,325-750 cal BP contributed to river use during the Archaic period, especially at elevations below 1,237 masl. Unfortunately, the resolution of environmental changes is greater than that of the archaeological record. As a result, while reduced occupation and exploitation in the Walker Lake basin would be expected for low lake periods at 2,500-2,000 cal BP, 1,325-750 cal BP, and 650-300 cal BP, these expectations cannot currently be tested and require additional research focused on chronology building.

My analyses of the Walker Lake basin archaeological record help to define patterns of land use and changing adaptations. When these data are combined with the broader archaeological record and the local geomorphological and environmental data, patterns of western Great Basin landscape use and cultural adaptations can be better understood. At the same time, the localized record helps to clarify small scale changes related to regional environmental shifts and adaptive strategies used across the western Great Basin. Integrating terrestrial and underwater research allowed the archaeological work to be directed and informed by the environmental record. The resulting integrative approach not only provided a more robust dataset, but also effectively of combined environmental and archaeological research to better understand how environmental changes impacted the archaeological record.

5.4. Future Work

My research in the Walker Lake basin has been invaluable for gathering new data about archaeology, geomorphology, and environmental history. This dissertation demonstrates the value of an integrative approach to research, as it shows effective, broad research methods, provides important updates to the history of Walker Lake and the regional environment, and uses statistics to tease out patterns in the archaeological record across the Walker Lake basin landscape. The results of each component inform one another, and provide not only a more refined record, but highlight existing areas for future work.

Within the Walker Lake basin, both underwater and terrestrial research is invaluable for a broader and more detailed understanding of the region. Terrestrially, an extensive surface survey program designed to identify sites associated with the lake, river, and washes across all three elevation ranges is essential for clarifying the nature of landscape use. While my dataset is relatively robust, consisting of 110 sites, these sites are unevenly distributed, and sites associated with Walker River are especially underrepresented. Similarly, less than half of the sites have temporally diagnostic materials, providing only a limited view of landscape use relative to different age components. Surveying more of the Walker Lake basin landscape will provide a better look at the distribution of sites and artifacts across time and space. Further, multiple sites recorded between 2015 and 2016 show evidence for buried materials and artifacts. Excavations on these sites would highlight stratigraphic contexts and have the potential to provide stronger chronological control for occupations and artifact components than do the temporally diagnostic projectile points used in this study. Such efforts would also provide a robust set of inter-site and intra-site spatial data that can be used to understand landscape use and adaptations across the Walker Lake basin during different periods.

Terrestrial efforts detailing the history of Walker lake and the local environment are also important. Multiple cutbanks identified during this survey contained preserved organic material and charcoal. Collecting and dating samples from each of these deposits would further refine the lake curve chronology by dating depositional changes preserved in the cutbanks. Identifying the types of paleoecological material in these deposits could also help clarify local environmental changes over time.

Within Walker Lake, there remain a multitude of research efforts that will expand upon our archaeological, climatic, and geomorphological understanding of the Walker Lake basin. An exhaustive sub-bottom survey program combined with the collection of new bathymetric data is essential. Sub-bottom survey using newer technology, such as the Edgetech 3400, would allow researchers to fully map the extent of preserved and buried shorelines and fluvial features within the lake, while at the same time collecting clearer evidence of preserved features in deep sediments. Using the newest parametric sub-bottom technology, such as Innomar's Quattro system, would provide even greater detail. Combining this sub-bottom survey with new bathymetric data would provide precise elevation information, allowing geomorphologists and archaeologists to reconstruct the ancient landscape with a high degree of accuracy.

Additional underwater testing and excavation focused on the preserved and buried features identified through sub-bottom testing will reveal additional information about lake-level history and environmental changes. Cores collected from the lake may be used for palynological analysis, providing high-resolution environmental reconstructions for the region. Test excavations using a systematic model similar to the shovel tests used along drowned drivelines in Lake Huron (Lemke 2015) would reveal the presence of buried, preserved archaeological sites along features identified in the sub-bottom profiles. The terrestrial survey performed during this study demonstrated that archaeological sites are preserved in the basin even after they have been drowned during high lake levels. These sites were consistently found along relict channel features in the Walker Lake basin. Sites preserved in similar contexts underneath the lake are likely to provide new evidence of landscape use and may contain preserved organic cultural materials. These sites would prove transformative for expanding our understanding of precontact cultures in the Walker Lake basin and across the Great Basin.

Beyond the Walker Lake basin, this research demonstrates the value of adopting similar methodological approaches in other areas. Northeast of Walker Lake, Pyramid Lake is another perennial waterbody where combining underwater and terrestrial methods is likely to provide an invaluable dataset. Such research would reveal important information about the history of the lake, its environment, and past cultures. Archaeologists may even consider adopting these methods to man-made waterbodies in the Great Basin. Research at Rye Patch Reservoir or the South Fork Reservoir would be ideal for investigating landscape use along the Humboldt River. More immediately, these results from the Walker Lake basin can be compared to similar perennial lake basins to identify variations and consistencies in landscape use. For instance, comparing the distribution of sites and artifacts associated with Eagle Lake in northeastern California and Malheur Lake in southeastern Oregon to the results from the Walker Lake basin would be help identify the range of landscape adaptations associated with Great Basin perennial water bodies near the Sierra Nevada front. In all, this dissertation provides an excellent model for pursuing new, novel research in the Great Basin and important conclusions for any archaeologist interested in the relationship between human land use adaptations and perennial lakes and water systems. Its foundation in the fundamental relationship between humans and their environment ensures this study is an essential contribution to Great Basin archaeological and environmental reconstructions.

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APPENDIX A

ARTIFACTS FROM THE WALKER LAKE BASIN

Imagery of artifacts with temporal associations:

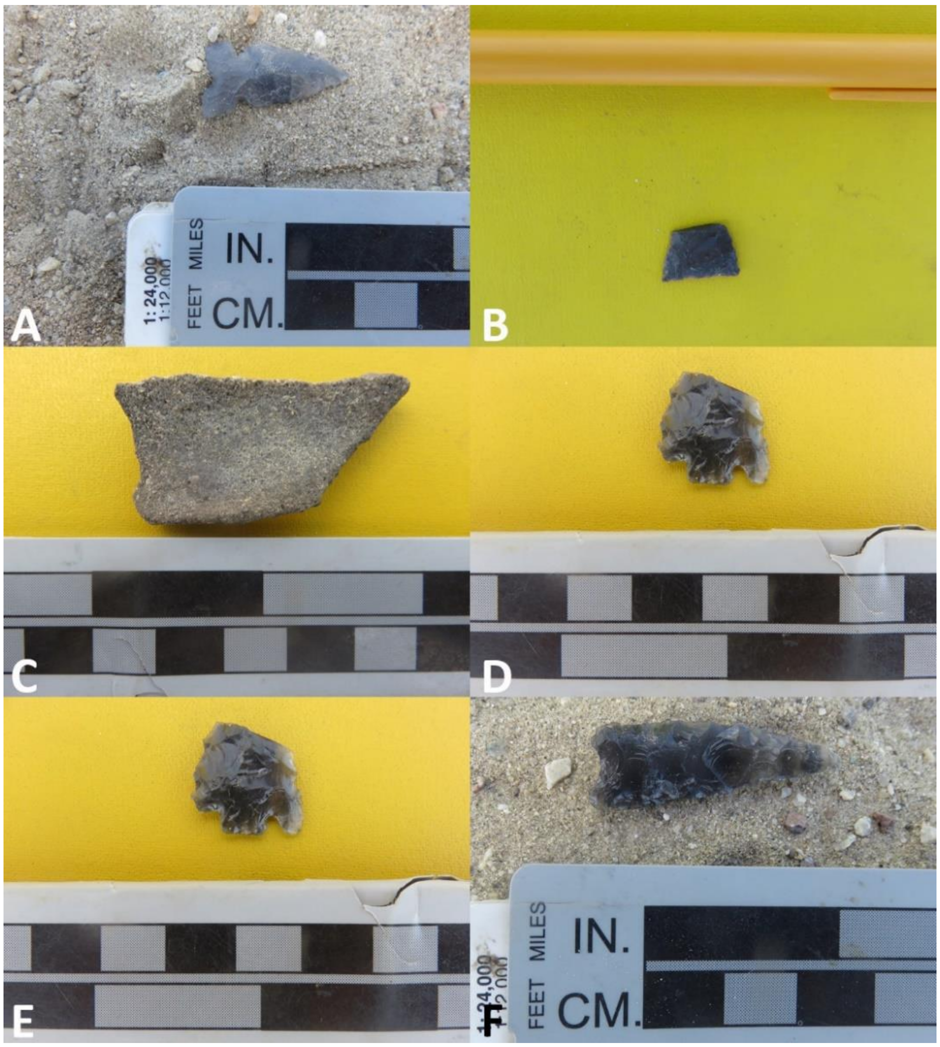

Figure A.1 Temporally diagnostic artifacts identified in summers 2015-16. (A) Artifact 2 from site Walk-15; Late Prehistoric obsidian Desert Side-notch point. (B) Artifact 2 from site Walk-16; Late Prehistoric Cottonwood Triangular obsidian point. (C) Artifact 2 from site Walk-8; Late Prehistoric brownware pot sherd. (D) Artifact 10 from site Walk-19; Late Archaic obsidian Rosegate point. (E) Artifact 5 from site Walk-28; Late Archaic chert Rosegate point. (F) Artifact 18 from site Walk-25; Middle Archaic obsidian Humboldt point.

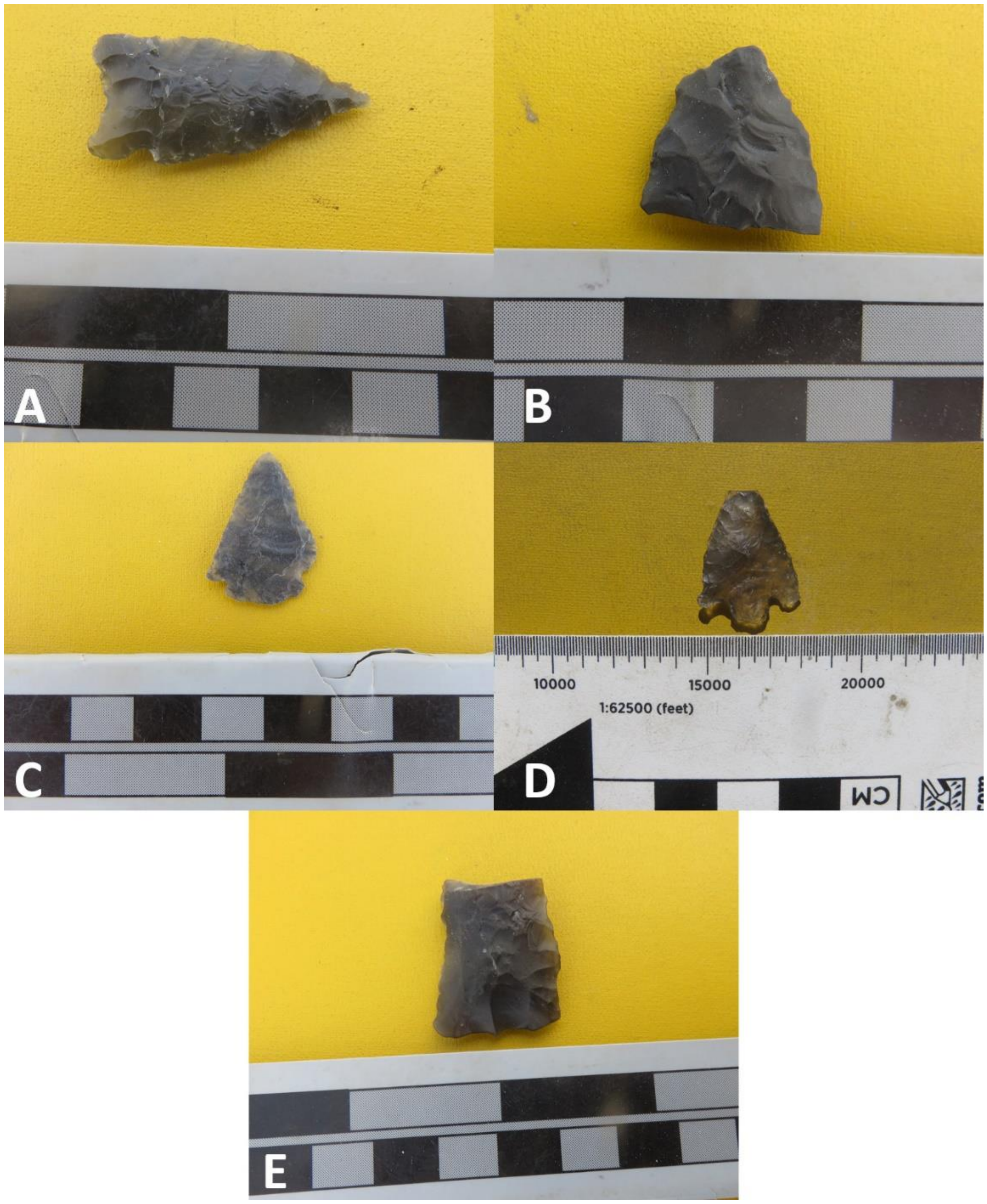

Figure A.2 Temporally diagnostic artifact identified in summers 2015-16. (A) Artifact 5 from site Walk-26; possible Middle Archaic obsidian Humboldt point. Point was out of Monitor Valley Key. (B) Artifact 1 from site Walk-4; possible Paleoindian obsidian Windust point base. (C) Artifact 9 from site Walk-19; Early-Middle Archaic obsidian Elko Corner-notch point. (D) Artifact 1 from site Walk-39; Early-Middle Archaic obsidian Gatecliff Contracting-stem point. (E) Artifact 5 from site Walk-4; possible Paleoindian obsidian Parmin point base.

Imagery of artifacts and site contexts indicative of resource processing activities, lithic reduction, net use, and near-shore adaptations:

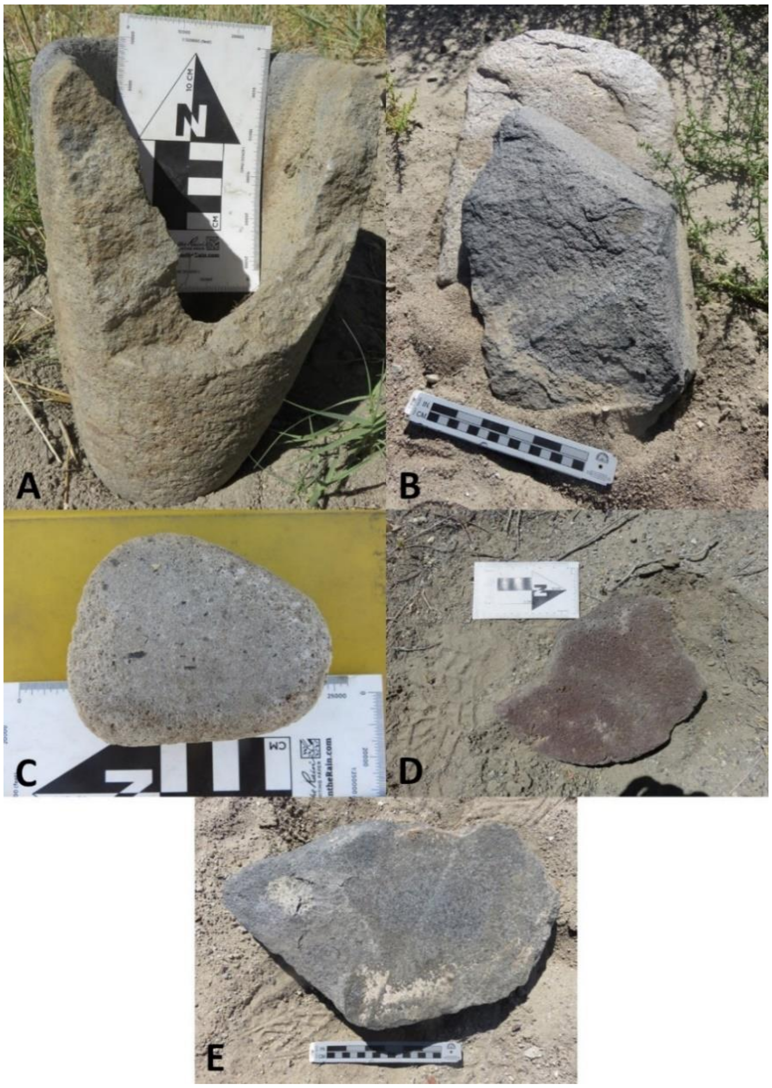

Figure A.3 Ground stone artifacts identified during fieldwork in summers 2015-16. (A) Artifact ISO-46; Deep granite mortar from Walker River channel indicative of processing activities. (B) Artifacts 11 and 12 stacked as found on site Walk-25. These artifacts near the historic Walker Lake shoreline are associated with near shore activities and adaptations. (C) Artifact 5 from site Walk-35; Hand stone indicative of processing activities. (D) Artifact 1 from site Walk-38; Milling slab indicative of processing activities. (E) Artifact 11 from site Walk-25; Milling slab indicative of processing activities and near-shore adaptations.

Figure A.4 Artifacts, ecofacts, and site elements indicative of processing. (A) Artifact 12 from site Walk-25; Milling slab indicative of processing activities and near-shore adaptations. (B) Bone B9 from site Walk-35; burned fish vertebrae indicative of fishing and processing activities. (C) Artifact 23 from site Walk-7; obsidian multidirectional core indicative of lithic reduction activities. (D) Artifact 8 from site Walk-19; exhausted chert multidirectional core indicative of lithic reduction activities. (E) Concentration 1 from site Walk-28. This concentration is indicative of processing activities and lithic reduction and contains lithics, charcoal staining, and burnt bone fragments.

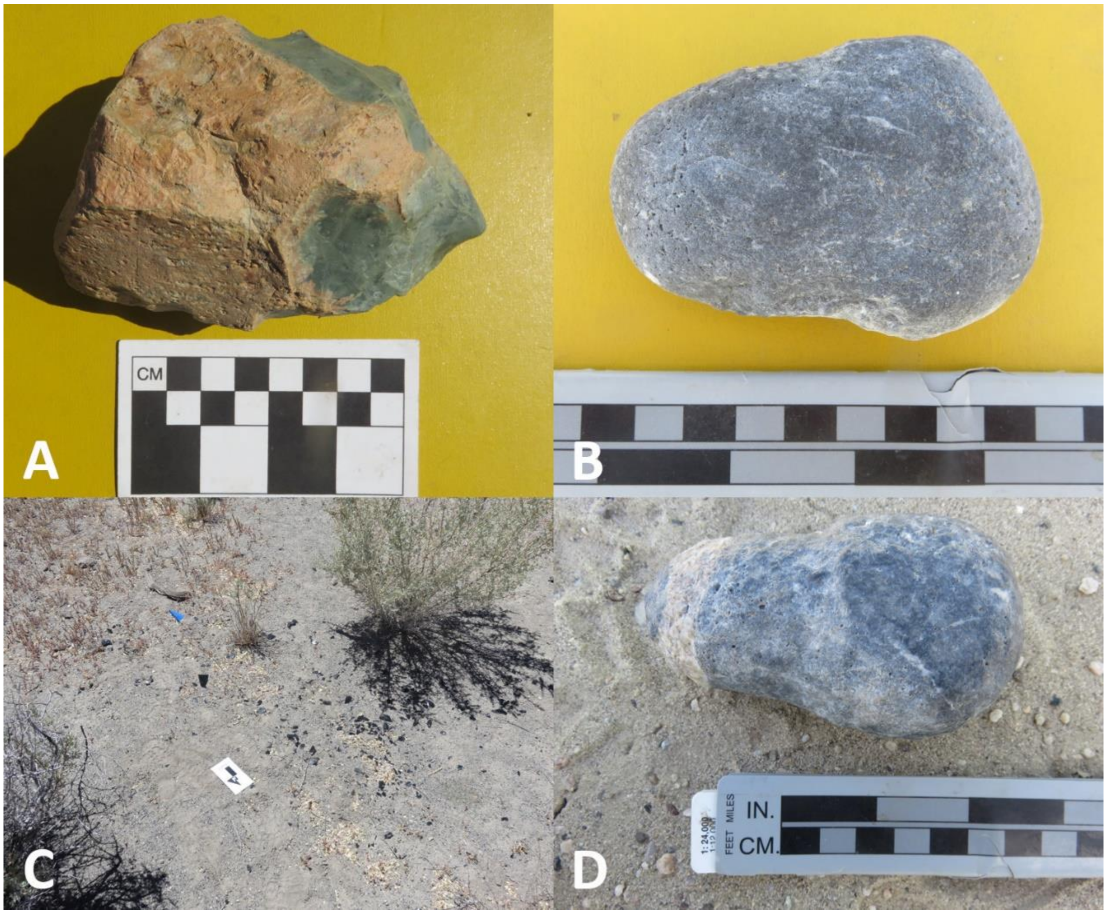

Figure A.5 Artifacts and site concentrations indicative of lithic and resource processing. (A) Artifact 1 from site Walk-21; exhausted chert multidirectional core indicative of lithic reduction activities. (B) Artifact 9 from site Walk-7; shaped stone likely used as a net weight an indicative of near-shore adaptations. (C) Concentration 2 from site Walk-40; dense concentration of obsidian flakes indicative of lithic reduction at the site. (D) Artifact 21 from site Walk-25; shaped stone likely used as a net weight an indicative of near-shore adaptations.

APPENDIX B

TEPHRA IMAGERY AND ANALYSES TABLES

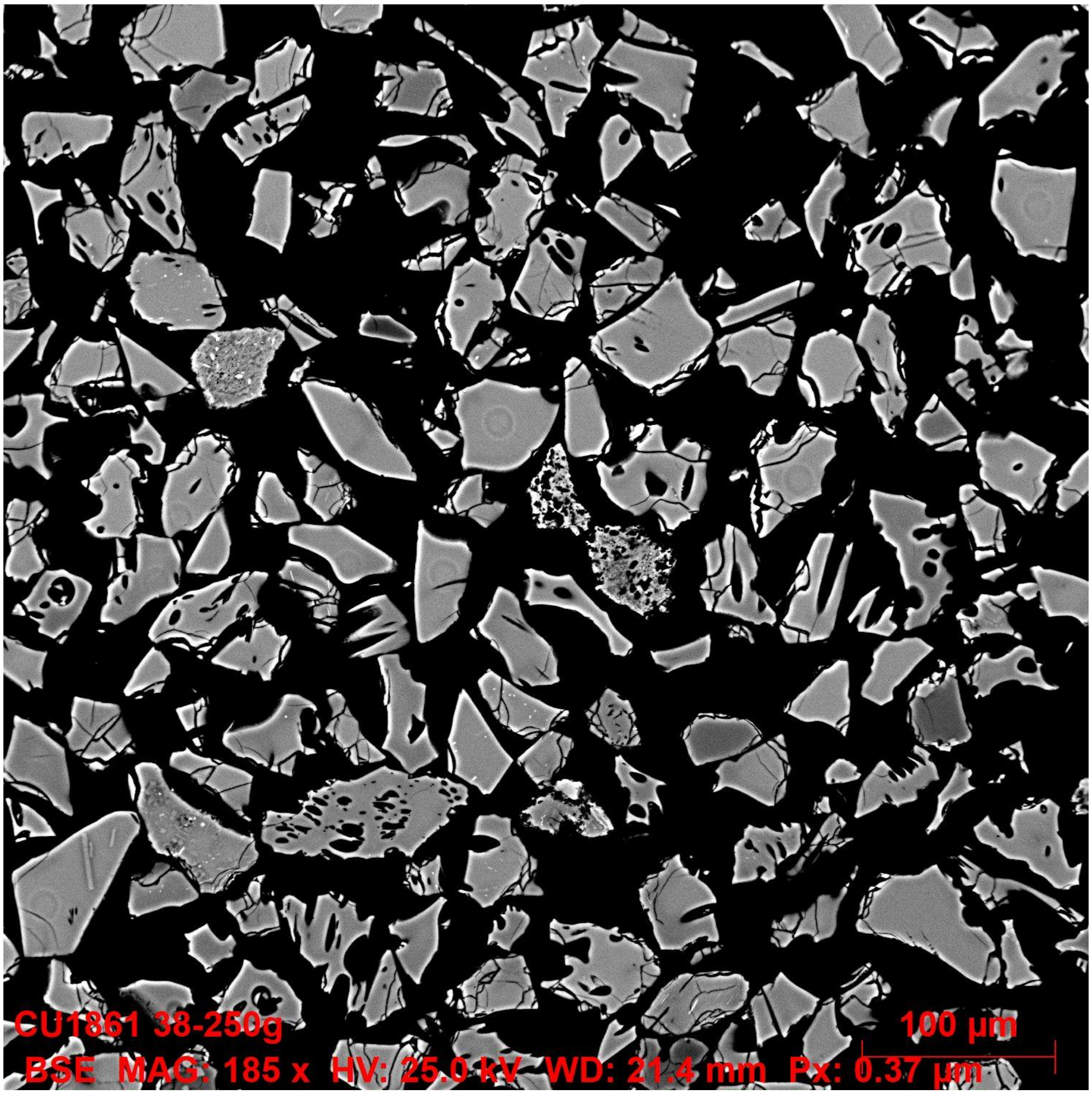

Figure B.1. Mounted glass separates from the TB-1 core tephra sample.

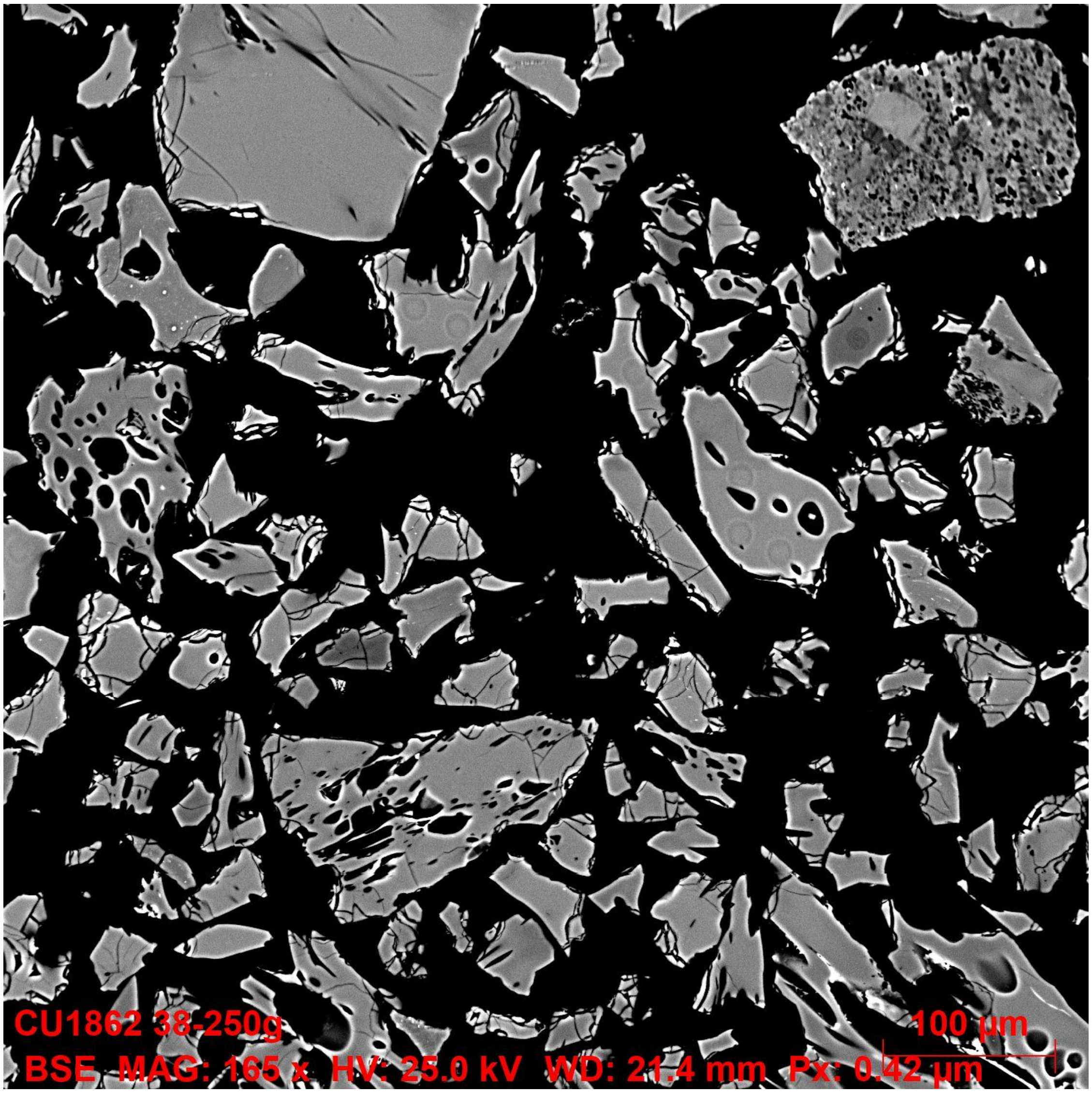

Figure B.2. Mounted glass separates from the TB-2 core tephra sample.

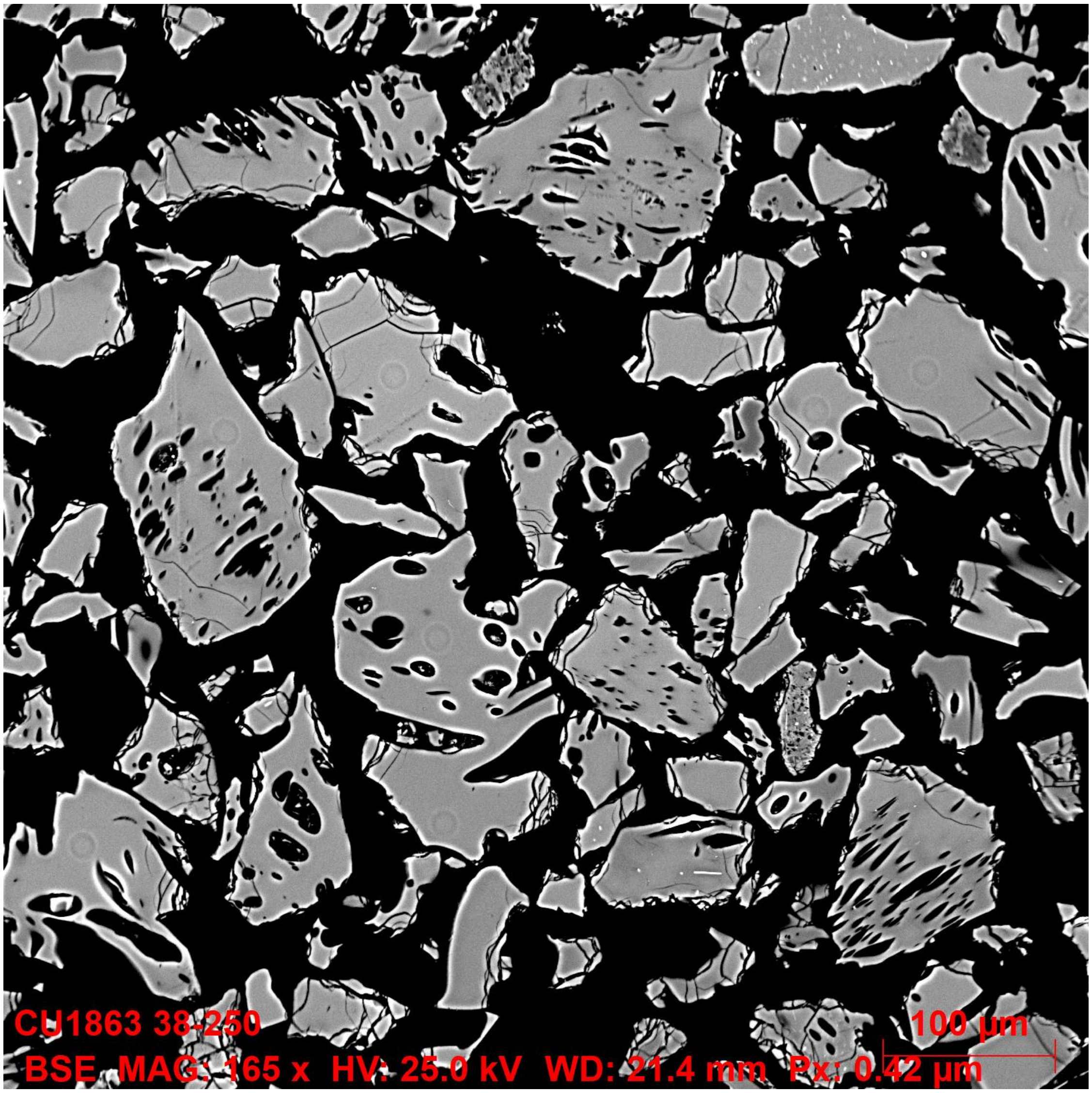

Figure B.3. Mounted glass separates from the TB-3 core tephra sample.

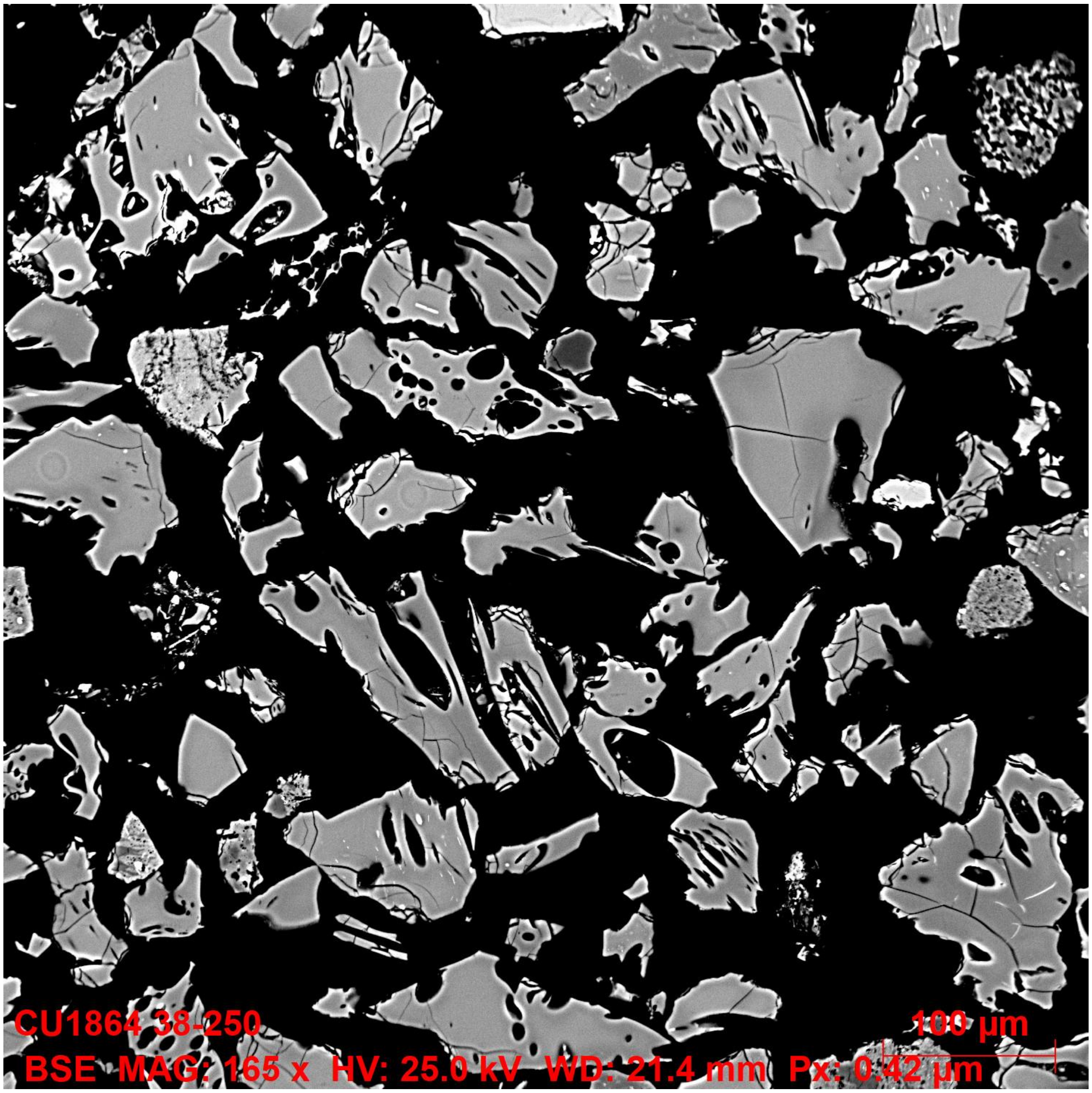

Figure B.4. Mounted glass separates for Cut Teph3 sample.

Table B.1. TB-1 Tephra sample electron probe microanalysis results showing raw wt. percentages. Trace-element blank-corrected and adjusted to match reference concentrations for Lipari, BHVO, and NKT glasses on a whole session, multi-standard consensus (weighted means) basis.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
CU1861	75.43	0.058	12.65	1.00	0.041	0.026	0.559	4.10	4.60	0.004	0.083	0.010	0.017	-0.005	0.022	98.65	1.35
CU1861	75.17	0.063	12.65	0.91	0.039	0.026	0.547	4.04	4.73	0.007	0.076	0.011	0.022	0.015	0.024	98.39	1.61
CU1861	74.26	0.057	12.51	0.98	0.044	0.021	0.541	3.98	4.70	0.006	0.075	0.001	0.027	-0.005	0.022	97.28	2.72
CU1861	75.79	0.057	12.74	0.99	0.042	0.027	0.548	4.06	4.59	0.006	0.081	0.011	0.024	0.010	0.017	99.05	0.95
CU1861	72.65	0.053	12.29	0.97	0.042	0.027	0.539	3.99	4.63	0.008	0.083	0.000	0.014	0.006	0.018	95.38	4.62
CU1861	75.05	0.056	12.70	0.99	0.044	0.030	0.543	4.04	4.73	0.010	0.076	0.013	0.033	0.013	0.012	98.40	1.60
CU1861	75.62	0.058	12.63	1.01	0.044	0.023	0.557	4.22	4.75	0.012	0.080	0.013	0.013	0.002	0.016	99.10	0.90
CU1861	74.74	0.063	12.46	0.96	0.041	0.025	0.550	4.00	4.76	0.009	0.075	0.005	0.025	0.005	0.016	97.79	2.21
CU1861	74.40	0.053	12.53	0.98	0.037	0.025	0.532	4.07	4.70	0.006	0.074	-0.006	0.023	0.001	0.023	97.49	2.51
CU1861	72.38	0.063	12.34	0.98	0.038	0.028	0.535	3.78	4.63	0.007	0.070	0.008	0.021	0.018	0.012	94.96	5.04
CU1861	73.21	0.068	12.21	0.97	0.047	0.026	0.538	3.82	4.58	0.007	0.063	-0.004	0.023	0.012	0.024	95.66	4.34
CU1861	75.18	0.063	12.76	1.01	0.038	0.030	0.547	4.12	4.69	0.008	0.073	0.013	0.019	0.005	0.014	98.63	1.37
CU1861	75.39	0.058	12.66	0.99	0.035	0.028	0.548	4.06	4.68	-0.001	0.071	0.013	0.025	-0.001	0.021	98.64	1.36

Table B.1. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
CU1861	75.66	0.055	12.81	0.97	0.045	0.029	0.552	4.02	4.76	0.005	0.075	-0.010	0.020	0.010	0.011	99.08	0.92
CU1861	75.18	0.061	12.62	1.00	0.044	0.028	0.549	4.07	4.66	0.006	0.077	0.008	0.024	0.007	0.020	98.40	1.60
CU1861	74.40	0.059	12.43	0.98	0.041	0.026	0.562	4.07	4.74	0.008	0.077	0.009	0.023	0.008	0.018	97.51	2.49
Average	**74.66**	**0.059**	**12.56**	**0.982**	**0.041**	**0.026**	**0.547**	**4.027**	**4.683**	**0.007**	**0.076**	**0.006**	**0.022**	**0.006**	**0.018**	**97.78**	**2.22**
StDev	1.06	0.004	0.18	0.023	0.003	0.002	0.008	0.106	0.061	0.003	0.005	0.007	0.005	0.007	0.004	1.34	1.34
Relative SD %	1.4%	7.0%	1.4%	2.4%	7.6%	9.0%	1.6%	2.6%	1.3%	42.9%	6.8%	126.4%	21.8%	104.1%	23.6%		

Outliers

CU1861	73.42	0.060	12.44	0.92	0.039	0.024	0.548	3.79	4.52	0.005	0.098	0.001	0.028	0.004	0.024	95.98	4.02
CU1861	71.98	0.044	12.69	0.83	0.048	0.025	0.635	3.52	4.43	0.004	0.082	0.004	0.022	0.001	0.012	94.37	5.63
CU1861	71.14	0.064	15.88	0.92	0.043	0.029	0.550	3.75	4.51	0.013	0.069	0.012	0.014	0.007	0.019	97.09	2.91
CU1861	68.72	0.055	11.78	0.93	0.044	0.023	0.511	3.58	4.27	0.006	0.119	-0.006	0.021	0.000	0.013	90.11	9.89
CU1861	66.13	-0.017	2.68	0.03	-0.008	-0.018	0.023	0.28	0.17	0.005	0.231	0.004	-0.017	-0.005	0.008	69.52	30.48

Table B.2. TB-1 Tephra sample electron probe microanalysis results showing normalized results accounting for halogens.

Lab No.	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cl	BaO	Rb_2O	SrO	ZrO_2	Total	H_2Odiff	NaTDI_COR %
CU1861	76.47	0.059	12.82	1.01	0.041	0.026	0.566	4.16	4.67	0.004	0.084	0.010	0.017	-0.005	0.022	100.00	1.35	12.1
CU1861	76.40	0.064	12.86	0.93	0.040	0.026	0.556	4.10	4.81	0.007	0.077	0.011	0.023	0.015	0.024	100.00	1.61	7.3
CU1861	76.34	0.058	12.87	1.01	0.045	0.021	0.556	4.09	4.83	0.006	0.077	0.001	0.027	-0.005	0.023	100.00	2.72	10.5
CU1861	76.52	0.058	12.86	1.00	0.042	0.027	0.553	4.10	4.63	0.006	0.082	0.011	0.024	0.010	0.018	100.00	0.95	9.8
CU1861	76.17	0.056	12.88	1.02	0.044	0.028	0.565	4.18	4.86	0.009	0.087	0.000	0.015	0.007	0.019	100.00	4.62	21.2
CU1861	76.26	0.057	12.91	1.01	0.044	0.031	0.552	4.11	4.81	0.010	0.077	0.013	0.034	0.013	0.013	100.00	1.60	7.4
CU1861	76.30	0.058	12.74	1.02	0.044	0.023	0.562	4.26	4.79	0.012	0.081	0.013	0.014	0.002	0.017	100.00	0.90	11.2
CU1861	76.43	0.064	12.74	0.98	0.042	0.026	0.562	4.09	4.86	0.009	0.077	0.005	0.026	0.005	0.017	100.00	2.21	8.6
CU1861	76.31	0.054	12.85	1.01	0.038	0.026	0.546	4.17	4.82	0.007	0.076	-0.006	0.024	0.002	0.023	100.00	2.51	11.4
CU1861	76.22	0.067	12.99	1.03	0.040	0.029	0.563	3.98	4.87	0.008	0.074	0.008	0.023	0.019	0.013	100.00	5.04	9.2
CU1861	76.53	0.072	12.77	1.02	0.049	0.027	0.562	4.00	4.79	0.007	0.065	-0.004	0.024	0.013	0.025	100.00	4.34	13.0
CU1861	76.23	0.063	12.93	1.02	0.039	0.030	0.555	4.18	4.76	0.008	0.074	0.013	0.019	0.005	0.014	100.00	1.37	9.7

Table B.2. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
CU1861	76.43	0.059	12.84	1.00	0.036	0.028	0.555	4.12	4.75	-0.001	0.072	0.013	0.025	-0.001	0.021	100.00	1.36	9.0
CU1861	76.36	0.056	12.93	0.98	0.046	0.029	0.558	4.06	4.81	0.006	0.075	-0.010	0.020	0.010	0.011	100.00	0.92	7.0
CU1861	76.40	0.062	12.82	1.02	0.045	0.028	0.558	4.14	4.73	0.006	0.078	0.008	0.025	0.007	0.020	100.00	1.60	9.0
CU1861	76.30	0.061	12.75	1.01	0.042	0.027	0.576	4.17	4.86	0.008	0.079	0.009	0.024	0.008	0.019	100.00	2.49	7.6
Average	**76.35**	**0.060**	**12.85**	**1.004**	**0.042**	**0.027**	**0.559**	**4.119**	**4.791**	**0.007**	**0.077**	**0.006**	**0.023**	**0.007**	**0.019**	**100.00**	**2.22**	**10.2**
StDev	0.11	0.005	0.07	0.025	0.003	0.002	0.007	0.071	0.069	0.003	0.005	0.008	0.005	0.007	0.004	0.00	1.34	3.4
Relative SD %	0.1%	7.6%	0.6%	2.5%	7.8%	9.0%	1.3%	1.7%	1.4%	42.7%	6.5%	126.3%	21.7%	104.5%	23.7%	0.0%	60.3%	

Outliers

CU1861	76.49	0.063	12.96	0.96	0.041	0.025	0.571	3.95	4.71	0.005	0.102	0.001	0.030	0.004	0.025	100.00	4.02	7.4
CU1861	76.27	0.047	13.45	0.88	0.051	0.027	0.673	3.73	4.69	0.005	0.087	0.004	0.023	0.001	0.013	100.00	5.63	11.7
CU1861	73.28	0.065	16.36	0.95	0.044	0.030	0.567	3.86	4.65	0.013	0.071	0.012	0.014	0.008	0.020	100.00	2.91	7.6
CU1861	76.27	0.061	13.07	1.03	0.049	0.026	0.567	3.97	4.74	0.006	0.132	-0.007	0.023	0.000	0.015	100.00	9.89	14.1
CU1861	95.13	-0.024	3.85	0.04	-0.011	-0.026	0.033	0.41	0.25	0.008	0.333	0.006	-0.024	-0.008	0.011	100.00	30.48	11.6

Table B.3. TB-2 Tephra sample electron probe microanalysis results showing raw wt. percentages. Trace-element blank-corrected and adjusted to match reference concentrations for Lipari, BHVO, and NKT glasses on a whole session, multi-standard consensus (weighted means) basis.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
CU1862	75.15	0.056	12.57	0.91	0.045	0.024	0.525	4.12	4.76	0.007	0.075	0.003	0.020	0.001	0.029	98.35	1.65
CU1862	76.37	0.053	12.91	1.03	0.047	0.025	0.542	4.11	4.60	0.010	0.076	-0.005	0.024	0.009	0.020	99.87	0.13
CU1862	74.76	0.060	12.44	1.04	0.045	0.026	0.538	4.08	4.60	0.007	0.073	0.010	0.022	0.013	0.020	97.78	2.22
CU1862	75.00	0.051	12.63	1.03	0.043	0.025	0.553	4.14	4.64	0.006	0.069	0.010	0.015	0.015	0.025	98.31	1.69
CU1862	75.54	0.061	12.68	1.02	0.043	0.026	0.534	4.21	4.63	0.006	0.074	0.016	0.025	0.016	0.021	98.95	1.05
CU1862	75.47	0.058	13.01	1.03	0.045	0.023	0.525	4.17	4.58	0.008	0.077	0.006	0.020	0.007	0.031	99.11	0.89
CU1862	75.63	0.058	12.53	1.01	0.042	0.027	0.540	4.13	4.69	0.009	0.073	0.003	0.027	0.015	0.020	98.87	1.13
CU1862	75.47	0.057	12.70	1.02	0.053	0.028	0.536	4.11	4.66	0.005	0.071	0.011	0.025	-0.003	0.023	98.83	1.17
CU1862	73.85	0.055	12.37	1.01	0.044	0.024	0.542	3.93	4.50	0.006	0.074	0.001	0.021	0.010	0.014	96.51	3.49
CU1862	74.81	0.063	12.47	1.03	0.043	0.027	0.556	4.04	4.67	0.005	0.078	0.013	0.021	0.010	0.018	97.91	2.09
CU1862	75.46	0.057	12.60	0.97	0.041	0.028	0.554	4.03	4.56	0.008	0.079	0.013	0.020	0.012	0.018	98.52	1.48
CU1862	75.51	0.055	12.58	1.01	0.044	0.026	0.561	4.24	4.59	0.012	0.074	0.014	0.019	0.003	0.034	98.84	1.16
CU1862	75.01	0.053	12.77	1.01	0.047	0.028	0.559	4.08	4.68	0.008	0.083	0.013	0.015	0.008	0.027	98.45	1.55
CU1862	75.31	0.061	12.66	1.03	0.052	0.026	0.557	3.97	4.70	0.002	0.075	0.008	0.028	-0.003	0.022	98.56	1.44
CU1862	75.29	0.059	12.60	1.01	0.050	0.026	0.539	4.10	4.65	0.005	0.073	0.002	0.022	0.008	0.023	98.52	1.48
CU1862	75.99	0.058	12.73	0.99	0.051	0.027	0.557	3.94	4.62	0.004	0.070	0.009	0.019	0.015	0.020	99.16	0.84
CU1862	75.42	0.058	12.59	1.01	0.043	0.025	0.553	3.97	4.63	0.005	0.079	-0.003	0.023	0.011	0.025	98.49	1.51
CU1862	73.95	0.055	12.38	1.00	0.045	0.025	0.536	4.05	4.64	0.010	0.080	0.007	0.021	0.001	0.025	96.88	3.12
CU1862	74.59	0.053	12.42	1.01	0.049	0.025	0.558	4.07	4.66	0.006	0.080	0.008	0.025	0.003	0.027	97.63	2.37
CU1862	75.75	0.059	12.72	1.02	0.047	0.025	0.535	4.18	4.61	0.004	0.086	0.005	0.025	0.003	0.019	99.15	0.85
CU1862	75.19	0.060	12.65	1.01	0.041	0.023	0.529	3.96	4.57	0.010	0.077	0.009	0.022	0.001	0.019	98.24	1.76

Table B.3 Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
Average	**75.22**	**0.057**	**12.62**	**1.010**	**0.046**	**0.026**	**0.544**	**4.078**	**4.630**	**0.007**	**0.076**	**0.007**	**0.022**	**0.007**	**0.023**	**98.43**	**1.57**
StDev	0.60	0.003	0.16	0.028	0.004	0.001	0.012	0.089	0.057	0.003	0.004	0.006	0.003	0.006	0.005	0.77	0.77
Relative SD %	0.8%	5.2%	1.3%	2.8%	7.8%	5.6%	2.1%	2.2%	1.2%	36.9%	5.4%	76.8%	15.9%	81.3%	21.0%		
Outliers																	
CU1862	71.90	0.056	12.06	1.02	0.037	0.024	0.524	4.12	4.16	0.007	0.072	-0.009	0.013	0.005	0.021	94.06	5.94

Table B.4. TB-2 Tephra sample electron probe microanalysis showing normalized results accounting for halogens.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
CU1862	76.41	0.057	12.78	0.92	0.046	0.024	0.534	4.19	4.84	0.007	0.076	0.003	0.020	0.001	0.030	100.00	1.65	16.5
CU1862	76.47	0.053	12.93	1.03	0.047	0.025	0.543	4.11	4.60	0.010	0.076	-0.005	0.024	0.009	0.020	100.00	0.13	15.9
CU1862	76.45	0.061	12.72	1.06	0.046	0.027	0.550	4.17	4.70	0.008	0.074	0.010	0.022	0.013	0.021	100.00	2.22	16.2
CU1862	76.29	0.052	12.84	1.05	0.044	0.025	0.563	4.21	4.72	0.006	0.070	0.010	0.015	0.016	0.025	100.00	1.69	11.8
CU1862	76.34	0.061	12.81	1.03	0.043	0.026	0.540	4.25	4.68	0.006	0.075	0.016	0.025	0.016	0.021	100.00	1.05	15.3
CU1862	76.14	0.058	13.12	1.04	0.045	0.023	0.530	4.21	4.62	0.008	0.078	0.006	0.020	0.007	0.031	100.00	0.89	15.9
CU1862	76.50	0.059	12.68	1.02	0.043	0.028	0.546	4.18	4.74	0.009	0.073	0.003	0.027	0.015	0.020	100.00	1.13	12.4

Table B.4. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
CU1862	76.37	0.058	12.86	1.03	0.054	0.028	0.542	4.16	4.72	0.005	0.072	0.011	0.026	-0.003	0.023	100.00	1.17	10.2
CU1862	76.52	0.057	12.82	1.04	0.046	0.025	0.562	4.08	4.66	0.006	0.077	0.002	0.021	0.010	0.015	100.00	3.49	17.4
CU1862	76.40	0.064	12.74	1.05	0.044	0.027	0.568	4.12	4.77	0.005	0.079	0.013	0.022	0.010	0.019	100.00	2.09	8.5
CU1862	76.60	0.057	12.79	0.98	0.041	0.029	0.563	4.09	4.63	0.008	0.081	0.013	0.020	0.012	0.018	100.00	1.48	7.0
CU1862	76.39	0.056	12.73	1.03	0.045	0.026	0.567	4.29	4.65	0.012	0.075	0.014	0.019	0.003	0.034	100.00	1.16	11.8
CU1862	76.19	0.054	12.97	1.03	0.048	0.028	0.568	4.14	4.75	0.008	0.085	0.014	0.015	0.008	0.028	100.00	1.55	7.7
CU1862	76.41	0.062	12.85	1.05	0.053	0.026	0.565	4.02	4.77	0.002	0.076	0.008	0.028	-0.003	0.023	100.00	1.44	7.8
CU1862	76.42	0.060	12.79	1.03	0.051	0.026	0.547	4.17	4.72	0.005	0.075	0.002	0.022	0.008	0.023	100.00	1.48	11.3
CU1862	76.64	0.058	12.84	1.00	0.052	0.027	0.561	3.97	4.65	0.004	0.071	0.010	0.019	0.016	0.020	100.00	0.84	8.0
CU1862	76.58	0.058	12.78	1.03	0.043	0.025	0.561	4.03	4.70	0.005	0.080	-0.003	0.023	0.011	0.026	100.00	1.51	9.9
CU1862	76.33	0.057	12.78	1.03	0.047	0.026	0.553	4.18	4.78	0.011	0.082	0.007	0.021	0.001	0.025	100.00	3.12	16.2
CU1862	76.40	0.055	12.72	1.04	0.050	0.026	0.572	4.17	4.77	0.006	0.082	0.009	0.026	0.003	0.027	100.00	2.37	12.5
CU1862	76.40	0.059	12.83	1.03	0.047	0.025	0.539	4.22	4.65	0.004	0.086	0.005	0.026	0.004	0.019	100.00	0.85	11.9
CU1862	76.54	0.061	12.88	1.03	0.042	0.024	0.539	4.04	4.66	0.010	0.079	0.009	0.023	0.001	0.019	100.00	1.76	12.2

Table B.4. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
Average	**76.42**	**0.058**	**12.82**	**1.027**	**0.046**	**0.026**	**0.553**	**4.143**	**4.705**	**0.007**	**0.077**	**0.007**	**0.022**	**0.008**	**0.023**	**100.00**	**1.57**	**12.2**
StDev	0.12	0.003	0.10	0.029	0.004	0.001	0.013	0.081	0.063	0.003	0.004	0.006	0.004	0.006	0.005	0.00	0.77	3.3
Relative SD %	0.2%	5.2%	0.8%	2.8%	7.7%	5.5%	2.3%	2.0%	1.3%	36.8%	5.5%	76.5%	15.8%	81.2%	20.9%	0.0%	48.9%	
Outliers																		
CU1862	76.44	0.060	12.82	1.09	0.040	0.026	0.557	4.38	4.42	0.008	0.076	-0.009	0.014	0.006	0.023	100.00	5.94	54.2

Table B.5. TB-3 Tephra sample electron probe microanalysis results showing raw wt. percentages. Trace-element blank-corrected and adjusted to match reference concentrations for Lipari, BHVO, and NKT glasses on a whole session, multi-standard consensus (weighted means) basis.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
Cu1863	75.38	0.065	12.57	0.92	0.051	0.027	0.548	4.01	4.79	0.006	0.074	0.009	0.020	0.011	0.029	98.55	1.45
Cu1863	75.89	0.063	12.91	0.92	0.047	0.020	0.569	4.17	4.66	0.008	0.063	-0.002	0.019	0.011	0.021	99.42	0.58
Cu1863	74.95	0.054	12.68	1.01	0.046	0.027	0.547	4.14	4.65	0.011	0.082	0.012	0.022	0.011	0.027	98.31	1.69
Cu1863	74.70	0.060	12.67	1.02	0.045	0.026	0.543	4.16	4.74	0.003	0.081	-0.003	0.028	0.006	0.015	98.14	1.86
Cu1863	76.40	0.064	12.86	1.06	0.050	0.025	0.537	4.01	4.81	0.013	0.077	0.005	0.024	0.009	0.023	100.01	-0.01

Table B.5. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
Cu1863	75.09	0.056	12.54	1.03	0.049	0.027	0.547	3.88	4.70	0.008	0.074	0.010	0.024	0.013	0.024	98.10	1.90
Cu1863	74.69	0.057	12.58	1.04	0.051	0.028	0.542	3.75	4.71	0.004	0.083	0.003	0.020	0.005	0.015	97.61	2.39
Cu1863	75.06	0.051	12.56	1.04	0.056	0.025	0.537	3.89	4.73	0.010	0.076	0.000	0.028	0.003	0.019	98.12	1.88
Cu1863	75.66	0.062	12.80	1.01	0.046	0.021	0.549	4.08	4.72	0.012	0.074	0.004	0.017	0.024	0.017	99.13	0.87
Cu1863	76.27	0.061	12.84	1.02	0.042	0.024	0.547	4.01	4.76	0.004	0.077	0.000	0.018	0.007	0.016	99.74	0.26
Cu1863	75.58	0.057	12.71	1.04	0.049	0.024	0.569	3.92	4.73	0.011	0.076	0.004	0.021	0.013	0.015	98.86	1.14
Cu1863	75.67	0.062	12.82	1.02	0.047	0.025	0.558	3.93	4.79	0.007	0.082	0.004	0.024	0.002	0.016	99.08	0.92
Cu1863	75.45	0.057	12.73	1.03	0.052	0.025	0.544	4.10	4.78	0.002	0.075	0.003	0.016	0.011	0.022	98.94	1.06
Cu1863	75.15	0.059	12.50	1.04	0.048	0.027	0.548	4.22	4.66	0.006	0.078	0.010	0.019	0.008	0.020	98.44	1.56
Cu1863	75.11	0.063	12.48	1.02	0.051	0.025	0.565	4.10	4.73	0.009	0.074	0.002	0.019	0.015	0.015	98.32	1.68
Cu1863	75.00	0.053	12.58	1.03	0.046	0.029	0.541	4.13	4.69	0.008	0.086	0.015	0.018	0.013	0.021	98.28	1.72
Cu1863	75.47	0.062	12.80	1.03	0.044	0.026	0.564	3.93	4.78	0.016	0.065	-0.002	0.021	0.005	0.025	98.88	1.12
Cu1863	75.40	0.059	12.72	1.02	0.054	0.030	0.549	4.01	4.75	0.006	0.086	-0.002	0.021	0.006	0.012	98.77	1.23
Cu1863	74.51	0.060	12.37	1.04	0.044	0.028	0.541	4.18	4.61	0.010	0.084	-0.003	0.021	0.008	0.018	97.57	2.43
Cu1863	75.58	0.061	12.83	1.04	0.055	0.026	0.553	4.10	4.82	0.009	0.079	0.002	0.022	0.016	0.026	99.26	0.74
Cu1863	76.02	0.063	12.75	1.03	0.048	0.022	0.551	3.80	4.86	0.012	0.076	0.010	0.016	0.008	0.019	99.32	0.68

Table B.5. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
Average	**75.38**	**0.059**	**12.68**	**1.020**	**0.049**	**0.026**	**0.550**	**4.024**	**4.736**	**0.008**	**0.077**	**0.004**	**0.021**	**0.010**	**0.020**	**98.71**	**1.29**
StDev	0.50	0.004	0.15	0.035	0.004	0.003	0.010	0.131	0.062	0.004	0.006	0.005	0.003	0.005	0.005	0.65	0.65
Relative SD %	0.7%	6.4%	1.2%	3.4%	7.6%	9.9%	1.8%	3.3%	1.3%	43.8%	7.6%	137.4%	16.3%	50.4%	23.4%		
Outliers																	
Cu1863	73.90	0.04	12.42	0.81	0.05	0.02	0.64	3.66	4.73	0.0048	0.0733	0.0020	0.0158	0.0096	0.0239	96.44	3.56
Cu1863	74.97	0.060	12.59	0.81	0.046	0.030	0.517	4.00	4.81	0.009	0.076	0.008	0.019	0.013	0.018	98.02	1.98

Table B.6. TB-3 Tephra sample electron probe microanalysis results showing normalized results accounting for halogens.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
Cu1863	76.49	0.066	12.76	0.93	0.052	0.028	0.556	4.06	4.87	0.006	0.075	0.009	0.020	0.011	0.029	100.00	1.45	8.7
Cu1863	76.34	0.063	12.98	0.93	0.047	0.020	0.572	4.19	4.69	0.008	0.063	-0.002	0.019	0.011	0.021	100.00	0.58	6.3
Cu1863	76.24	0.055	12.90	1.03	0.047	0.027	0.556	4.22	4.73	0.011	0.083	0.012	0.023	0.011	0.027	100.00	1.69	10.3
Cu1863	76.12	0.061	12.91	1.04	0.046	0.026	0.554	4.24	4.83	0.003	0.083	-0.003	0.029	0.006	0.015	100.00	1.86	9.2
Cu1863	76.40	0.064	12.86	1.06	0.050	0.025	0.537	4.01	4.80	0.013	0.077	0.005	0.024	0.009	0.023	100.00	-0.01	7.8
Cu1863	76.54	0.057	12.78	1.05	0.050	0.028	0.558	3.95	4.79	0.008	0.076	0.010	0.024	0.013	0.025	100.00	1.90	6.4

Table B.6. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
Cu1863	76.51	0.059	12.89	1.07	0.052	0.029	0.555	3.84	4.82	0.004	0.085	0.003	0.021	0.005	0.015	100.00	2.39	7.9
Cu1863	76.50	0.052	12.80	1.06	0.057	0.026	0.547	3.96	4.82	0.010	0.078	0.000	0.029	0.003	0.020	100.00	1.88	4.9
Cu1863	76.32	0.062	12.91	1.02	0.047	0.021	0.554	4.11	4.76	0.012	0.074	0.004	0.017	0.024	0.017	100.00	0.87	7.9
Cu1863	76.47	0.061	12.87	1.03	0.043	0.024	0.548	4.03	4.77	0.004	0.078	0.000	0.018	0.007	0.016	100.00	0.26	7.2
Cu1863	76.45	0.058	12.86	1.05	0.050	0.024	0.576	3.96	4.78	0.011	0.077	0.004	0.021	0.013	0.015	100.00	1.14	4.4
Cu1863	76.37	0.063	12.93	1.03	0.047	0.025	0.563	3.96	4.83	0.007	0.082	0.004	0.024	0.002	0.016	100.00	0.92	7.7
Cu1863	76.26	0.057	12.86	1.04	0.053	0.025	0.549	4.15	4.83	0.002	0.075	0.003	0.016	0.011	0.022	100.00	1.06	10.3
Cu1863	76.35	0.059	12.70	1.06	0.049	0.028	0.557	4.28	4.74	0.006	0.079	0.010	0.019	0.008	0.020	100.00	1.56	7.2
Cu1863	76.39	0.065	12.69	1.04	0.052	0.025	0.574	4.17	4.81	0.010	0.075	0.002	0.020	0.015	0.016	100.00	1.68	7.2
Cu1863	76.31	0.054	12.80	1.05	0.046	0.030	0.550	4.20	4.77	0.008	0.088	0.016	0.018	0.014	0.021	100.00	1.72	9.8
Cu1863	76.32	0.063	12.94	1.05	0.045	0.027	0.570	3.97	4.84	0.017	0.066	-0.002	0.021	0.006	0.025	100.00	1.12	9.0
Cu1863	76.34	0.059	12.88	1.03	0.055	0.030	0.556	4.06	4.81	0.006	0.087	-0.002	0.021	0.006	0.013	100.00	1.23	8.8
Cu1863	76.37	0.061	12.68	1.07	0.046	0.029	0.555	4.28	4.73	0.010	0.086	-0.003	0.022	0.008	0.019	100.00	2.43	10.4
Cu1863	76.15	0.061	12.93	1.04	0.056	0.026	0.557	4.13	4.85	0.009	0.080	0.002	0.022	0.016	0.026	100.00	0.74	9.2
Cu1863	76.53	0.064	12.84	1.03	0.048	0.022	0.554	3.83	4.90	0.012	0.077	0.010	0.016	0.008	0.019	100.00	0.68	6.6

Table B.6. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR%
Average	**76.37**	**0.060**	**12.85**	**1.034**	**0.049**	**0.026**	**0.557**	**4.077**	**4.798**	**0.008**	**0.078**	**0.004**	**0.021**	**0.010**	**0.020**	**100.00**	**1.29**	**8.0**
StDev	0.12	0.004	0.09	0.037	0.004	0.003	0.010	0.136	0.051	0.004	0.006	0.005	0.003	0.005	0.005	0.00	0.65	1.7
Relative SD %	0.2%	6.1%	0.7%	3.6%	7.7%	10.2%	1.7%	3.3%	1.1%	43.7%	7.8%	137.7%	16.5%	50.3%	23.3%	0.0%	50.3%	
Outliers																		
Cu1863	76.63	0.043	12.88	0.84	0.048	0.022	0.66	3.80	4.91	0.0050	0.0760	0.0020	0.0164	0.0100	0.0248	100.00	3.56	9.1
Cu1863	76.49	0.062	12.84	0.83	0.047	0.030	0.528	4.08	4.90	0.009	0.077	0.009	0.020	0.013	0.019	100.00	1.98	9.4

Table B.7. CutTeph-3 Tephra sample electron probe microanalysis results showing raw wt. percentages. Trace-element blank-corrected and adjusted to match reference concentrations for Lipari, BHVO, and NKT glasses on a whole session, multi-standard consensus (weighted means) basis.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
CU1864	75.76	0.063	12.78	1.02	0.050	0.025	0.560	3.97	4.74	0.006	0.071	0.004	0.018	0.005	0.026	99.14	0.86
CU1864	75.26	0.061	12.52	1.03	0.053	0.026	0.563	3.99	4.69	0.005	0.077	0.003	0.014	0.003	0.021	98.35	1.65
CU1864	76.15	0.057	12.72	1.03	0.047	0.024	0.546	4.06	4.82	0.010	0.071	0.003	0.022	0.012	0.022	99.63	0.37
CU1864	75.43	0.068	12.74	1.02	0.043	0.026	0.546	4.17	4.68	0.008	0.073	0.012	0.022	-0.006	0.014	98.89	1.11
CU1864	74.27	0.061	12.51	1.01	0.048	0.025	0.542	3.82	4.66	0.005	0.079	0.006	0.025	0.000	0.019	97.11	2.89
CU1864	76.20	0.062	12.73	0.98	0.052	0.025	0.531	3.97	4.78	0.007	0.074	0.002	0.021	0.015	0.023	99.50	0.50
CU1864	75.62	0.057	12.64	1.01	0.048	0.028	0.545	4.07	4.70	0.009	0.068	0.013	0.024	-0.001	0.014	98.88	1.12

Table B.7. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2O diff
CU1864	74.98	0.063	12.63	1.03	0.047	0.026	0.546	3.90	4.73	0.006	0.072	0.007	0.035	-0.008	0.015	98.13	1.87
CU1864	77.44	0.063	13.00	1.03	0.049	0.026	0.546	4.02	4.70	0.000	0.077	0.005	0.015	0.002	0.018	101.03	-1.03
CU1864	74.51	0.057	12.37	1.02	0.043	0.025	0.531	3.97	4.50	0.010	0.081	0.001	0.017	0.013	0.017	97.21	2.79
CU1864	75.49	0.066	12.69	0.88	0.046	0.025	0.529	3.87	4.60	0.011	0.074	0.001	0.024	-0.007	0.012	98.35	1.65
CU1864	74.32	0.054	12.58	1.00	0.048	0.024	0.531	4.06	4.46	0.011	0.083	0.009	0.028	-0.002	0.011	97.25	2.75
CU1864	74.99	0.062	12.68	1.02	0.049	0.024	0.538	4.12	4.64	0.004	0.072	0.005	0.021	0.009	0.022	98.30	1.70
CU1864	75.92	0.061	12.72	1.03	0.048	0.025	0.543	4.15	4.66	0.006	0.077	0.004	0.015	0.002	0.020	99.33	0.67
CU1864	75.44	0.059	12.64	1.01	0.049	0.025	0.545	3.99	4.59	0.002	0.078	0.011	0.024	0.014	0.021	98.54	1.46
CU1864	75.83	0.054	12.62	1.03	0.044	0.024	0.541	4.01	4.64	0.003	0.076	0.009	0.021	0.004	0.018	98.96	1.04
CU1864	75.33	0.058	12.65	1.00	0.047	0.027	0.551	4.26	4.62	0.005	0.077	-0.006	0.023	0.012	0.012	98.71	1.29
CU1864	75.78	0.057	12.64	0.95	0.042	0.022	0.535	4.00	4.67	0.005	0.076	0.014	0.018	0.004	0.017	98.87	1.13
CU1864	74.00	0.060	12.44	1.00	0.045	0.027	0.538	4.05	4.57	0.004	0.079	0.005	0.010	0.001	0.023	96.90	3.10
CU1864	76.33	0.060	12.78	1.00	0.043	0.027	0.541	3.94	4.61	0.008	0.072	0.006	0.016	0.010	0.012	99.51	0.49
CU1864	75.46	0.061	12.77	1.03	0.051	0.029	0.540	3.90	4.71	0.012	0.072	-0.001	0.017	0.002	0.022	98.72	1.28
CU1864	75.27	0.061	12.78	1.00	0.045	0.023	0.523	4.03	4.57	0.001	0.077	0.002	0.018	-0.001	0.005	98.44	1.56
CU1864	75.36	0.064	12.60	1.00	0.047	0.026	0.537	4.19	4.57	0.001	0.071	-0.004	0.021	0.007	0.014	98.56	1.44
Average	**75.44**	**0.060**	**12.66**	**1.005**	**0.047**	**0.025**	**0.541**	**4.023**	**4.648**	**0.006**	**0.075**	**0.005**	**0.021**	**0.004**	**0.017**	**98.62**	**1.38**
StDev	0.76	0.003	0.13	0.034	0.003	0.002	0.009	0.107	0.084	0.003	0.004	0.005	0.005	0.007	0.005	0.93	0.93
Relative SD %	1.0%	5.8%	1.0%	3.4%	6.3%	6.5%	1.7%	2.7%	1.8%	55.6%	4.9%	104.2%	25.4%	167.7%	28.8%		

Table B.8. TB-3 Tephra sample electron probe microanalysis showing normalized results accounting for halogens.

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
CU1864	76.42	0.064	12.89	1.03	0.050	0.026	0.565	4.01	4.78	0.006	0.071	0.004	0.018	0.005	0.026	100.00	0.86	4.9
CU1864	76.52	0.062	12.73	1.04	0.054	0.027	0.573	4.05	4.77	0.005	0.078	0.003	0.015	0.003	0.022	100.00	1.65	7.7
CU1864	76.43	0.057	12.77	1.04	0.047	0.024	0.548	4.07	4.84	0.010	0.072	0.003	0.022	0.012	0.022	100.00	0.37	9.7
CU1864	76.28	0.069	12.89	1.03	0.044	0.026	0.552	4.22	4.73	0.008	0.073	0.013	0.022	-0.006	0.014	100.00	1.11	8.1
CU1864	76.48	0.062	12.88	1.04	0.050	0.026	0.558	3.94	4.80	0.005	0.081	0.006	0.025	0.000	0.020	100.00	2.89	6.7
CU1864	76.58	0.062	12.79	0.99	0.053	0.026	0.534	3.99	4.80	0.007	0.074	0.002	0.021	0.015	0.023	100.00	0.50	5.8
CU1864	76.47	0.058	12.78	1.02	0.048	0.028	0.551	4.12	4.75	0.009	0.069	0.013	0.024	-0.001	0.015	100.00	1.12	8.4
CU1864	76.41	0.064	12.87	1.05	0.048	0.027	0.557	3.98	4.82	0.006	0.073	0.008	0.036	-0.008	0.015	100.00	1.87	5.6
CU1864	76.65	0.062	12.86	1.02	0.049	0.026	0.540	3.98	4.65	0.000	0.077	0.005	0.015	0.002	0.018	100.00	-1.03	7.6
CU1864	76.65	0.059	12.73	1.04	0.045	0.026	0.546	4.09	4.63	0.011	0.084	0.001	0.017	0.013	0.017	100.00	2.79	8.4
CU1864	76.76	0.067	12.90	0.89	0.047	0.026	0.538	3.94	4.67	0.012	0.075	0.001	0.024	-0.007	0.013	100.00	1.65	4.9
CU1864	76.42	0.055	12.93	1.03	0.049	0.024	0.546	4.17	4.58	0.011	0.085	0.009	0.029	-0.002	0.011	100.00	2.75	9.7
CU1864	76.29	0.063	12.90	1.03	0.050	0.024	0.548	4.19	4.72	0.004	0.073	0.005	0.022	0.009	0.022	100.00	1.70	7.5
CU1864	76.44	0.062	12.80	1.04	0.048	0.025	0.546	4.18	4.69	0.006	0.078	0.004	0.016	0.002	0.020	100.00	0.67	9.9
CU1864	76.55	0.060	12.83	1.03	0.050	0.025	0.553	4.05	4.66	0.003	0.079	0.012	0.024	0.014	0.021	100.00	1.46	5.9
CU1864	76.62	0.055	12.75	1.04	0.044	0.025	0.547	4.05	4.69	0.003	0.076	0.010	0.022	0.004	0.018	100.00	1.04	4.2

Table B.8. Continued

Lab No.	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Cl	BaO	Rb2O	SrO	ZrO2	Total	H2Odiff	NaTDI_COR %
CU1864	76.32	0.059	12.82	1.01	0.047	0.027	0.558	4.32	4.68	0.005	0.078	-0.006	0.023	0.013	0.012	100.00	1.29	11.3
CU1864	76.64	0.058	12.79	0.96	0.043	0.022	0.541	4.05	4.73	0.005	0.076	0.014	0.018	0.004	0.017	100.00	1.13	4.7
CU1864	76.37	0.062	12.84	1.03	0.046	0.028	0.555	4.18	4.72	0.004	0.081	0.005	0.011	0.001	0.024	100.00	3.10	10.8
CU1864	76.71	0.060	12.85	1.01	0.044	0.027	0.544	3.96	4.64	0.008	0.072	0.006	0.016	0.010	0.013	100.00	0.49	6.3
CU1864	76.44	0.061	12.94	1.04	0.052	0.029	0.547	3.95	4.77	0.012	0.073	-0.001	0.018	0.002	0.022	100.00	1.28	4.5
CU1864	76.46	0.062	12.98	1.02	0.046	0.023	0.531	4.09	4.64	0.001	0.079	0.002	0.018	-0.001	0.006	100.00	1.56	7.2
CU1864	76.46	0.064	12.78	1.02	0.048	0.026	0.545	4.26	4.64	0.001	0.072	-0.004	0.022	0.008	0.014	100.00	1.44	9.9
Average	**76.49**	**0.061**	**12.84**	**1.019**	**0.048**	**0.026**	**0.549**	**4.080**	**4.713**	**0.006**	**0.076**	**0.005**	**0.021**	**0.004**	**0.018**	**100.00**	**1.38**	**7.4**
StDev	0.13	0.003	0.07	0.034	0.003	0.002	0.010	0.108	0.069	0.003	0.004	0.005	0.005	0.007	0.005	0.00	0.93	2.1
Relative SD %	0.2%	5.7%	0.5%	3.3%	6.2%	6.5%	1.7%	2.7%	1.5%	55.7%	5.4%	104.1%	25.7%	168.1%	28.7%	0.0%	67.8%	

APPENDIX C

SITE AGE COMPONENTS AND LANDFORMS

Table C.1. Distribution temporal components for sites with temporally diagnostic artifacts.

Sites	Paleoindian	Early-Middle Archaic	Late Archaic	Late Prehistoric	Number of Temporal Periods
26Mn1547		X			1
26MN1548			X		1
26MN1550	X				1
CRNV-03-6656				X	1
CRNV-03-6657		X			1
CrNV-03-6673				X	1
CrNV-03-6680	X				1
CrNV-03-683	X				1
CRNV-32-5187	X				1
Walk-04	X				1
Walk-07				X	1
Walk-08				X	1
Walk-15				X	1
Walk-16				X	1
Walk-17				X	1
Walk-22				X	1
Walk-26		X			1
Walk-27				X	1
Walk-29			X		1
Walk-35			X		1
Walk-39		X			1
Walk-40		X			1
CrNV-03-2584A		X	X		2
CRNV-03-6216		X	X		2
CrNV-03-6658	X			X	2
CRNV-03-6683		X		X	2
Walk-03			X	X	2
Walk-21		X		X	2
Walk-25		X	X		2

Table C.1. Continued

Sites	Paleoindian	Early- Middle Archaic	Late Archaic	Late Prehistoric	Number of Temporal Periods
Walk-28		X	X		2
Walk-01	X	X		X	3
Walk-18	X		X	X	3
Walk-19		X	X	X	3
Total	**9**	**13**	**10**	**16**	**47**

Table C.2. Landscape categories and distance measurements by site.

Sites	Elevation Level	Closest primary landform	Elevation	Distance to Shoreline (m)	Distance to Holocene Shoreline (m)	Distance to Walker River Channel (m)	Distance to Wash (m)
26MN1532	Above Sehoo	Wash	1526.04	6597.75	12329.28	38529.98	2.49
26MN1533	Above Sehoo	Wash	1541.22	6676.45	12376.17	38584.78	41.74
26MN1534	Above Sehoo	Wash	1532.75	5941.60	11190.61	37451.35	14.64
26MN1535	Above Sehoo	Wash	1470.88	4579.23	9793.90	36039.53	10.96
26MN1536	Above Sehoo	Wash	1529.96	5517.14	9254.24	35645.35	37.87
26MN1537	Above Sehoo	Wash	1448.54	4065.09	9335.59	35563.67	119.00
26Mn1538	Above Sehoo	Wash	1444.72	3846.22	8874.26	35126.27	272.34
26Mn1539	Above Sehoo	Wash	2036.06	12881.53	17791.49	44170.43	384.86
26MN1540	Above Sehoo	Wash	1446.29	3668.10	8226.33	34515.99	86.36
26MN1541	Above Sehoo	Wash	1427.9	2855.21	6438.18	32823.30	19.30
26Mn1542	Above Sehoo	Wash	1433.56	3491.02	8486.15	34733.51	315.20
26Mn1543	Above Sehoo	Wash	1420.36	3165.14	8257.03	34485.28	281.83
26Mn1544	Above Sehoo	Wash	1402.02	2547.05	7512.50	33734.67	542.46
26Mn1545	Above Sehoo	Wash	1375.31	1561.01	6237.44	32469.23	373.86
26MN1546	Above Sehoo	Wash	1635.54	7779.80	12242.59	38617.63	152.52
26Mn1547	Above Sehoo	Wash	1607.43	7015.60	10915.74	37307.31	298.67
26MN1548	Above Sehoo	Wash	1535.45	5646.88	9272.16	35663.23	51.07
26MN1549	Above Sehoo	Wash	1558.9	6767.90	12433.91	38650.50	51.64
26MN1550	Historic-Sehoo	Lake	1275.48	1252.79	1252.79	26344.27	4938.28
26MN1551	Above Sehoo	Wash	1380.22	1383.42	5024.20	31383.06	19.12
26MN1552	Above Sehoo	Wash	1609.77	7439.65	11564.07	37953.41	17.02
26MN1567	Above Sehoo	Wash	1516.46	4191.81	7760.95	34084.47	211.06

Table C.2. Continued

Sites	Elevation Level	Closest primary landform	Elevation	Distance to Shoreline (m)	Distance to Holocene Shoreline (m)	Distance to Walker River Channel (m)	Distance to Wash (m)
CrNV-03-2584A	Historic-Sehoo	Lake	1333.5	10269.74	19294.42	39332.87	2549.39
CrNV-03-3228	Below Historic	Lake	1241.56	81.04	81.04	20884.92	8864.22
CrNV-03-3403	Above Sehoo	Uplands	1691.95	8459.26	25797.65	30603.18	17018.54
CrNV-03-3406	Above Sehoo	Uplands	1670.3	6122.99	23827.09	28650.61	15080.57
CRNV-03-5255	Above Sehoo	Wash	1422.44	3450.12	32658.36	7826.34	142.36
CRNV-03-5256	Above Sehoo	Wash	1469.5	4677.89	32455.79	8855.10	225.75
CrNV-03-5258	Above Sehoo	Wash	1375.78	9781.45	39061.01	12837.11	255.29
CRNV-03-6216	Above Sehoo	Wash	1537.72	66764.35	80282.18	75535.16	175.57
CRNV-03-6644	Historic-Sehoo	Wash	1318.62	1081.66	7727.85	1152.62	76.62
CrNV-03-6647	Below Historic	Lake	1248.63	69.04	69.04	20120.70	316.14
CrNV-03-6649	Below Historic	Lake	1250.59	21.05	21.05	20440.53	92.99
CrNV-03-6650	Below Historic	Lake	1244.48	65.24	65.24	19972.81	508.63
CrNV-03-6652	Historic-Sehoo	River	1315.82	737.81	3519.08	1263.09	3764.76
CRNV-03-6653	Above Sehoo	Wash	1346.78	184.64	8570.82	11420.76	125.40
CRNV-03-6654	Above Sehoo	Wash	1482.15	8313.17	14666.38	12043.58	199.77
CRNV-03-6655	Historic-Sehoo	Wash	1334.17	190.18	7447.51	1860.60	40.32
CRNV-03-6656	Historic-Sehoo	Wash	1332.9	249.46	7511.77	1809.30	93.77
CRNV-03-6657	Above Sehoo	Wash	1425.84	3899.00	8696.69	7265.65	213.32
CrNV-03-6658	Historic-Sehoo	Wash	1321.4	827.79	21305.12	418.28	374.08
CRNV-03-6659	Historic-Sehoo	River	1296.4	944.78	21407.89	157.20	499.65
CRNV-03-6672	Historic-Sehoo	Lake	1293.49	163.06	163.06	13853.63	768.67
CrNV-03-6673	Historic-Sehoo	Lake	1287.12	146.73	146.73	2910.26	12173.89

Table C.2. Continued

Sites	Elevation Level	Closest primary landform	Elevation	Distance to Shoreline (m)	Distance to Holocene Shoreline (m)	Distance to Walker River Channel (m)	Distance to Wash (m)
CRNV-03-6674	Historic-Sehoo	Wash	1279.18	793.66	11269.10	15056.52	231.74
CRNV-03-6675	Above Sehoo	Wash	1344.3	2314.62	15527.95	16873.03	108.93
CRNV-03-6676	Above Sehoo	Wash	1459.38	5760.03	11454.90	7897.87	182.71
CrNV-03-6677	Historic-Sehoo	Wash	1328.18	446.70	7378.57	1444.04	234.40
CRNV-03-6678	Historic-Sehoo	Wash	1318.5	1045.51	7787.75	1181.95	140.11
CrNV-03-6680	Historic-Sehoo	Wash	1279.89	2632.96	3225.86	3737.88	655.63
CRNV-03-6683	Above Sehoo	Wash	2201.83	5995.43	6559.24	12854.26	21.68
CrNV-03-680	Historic-Sehoo	Lake	1334.41	10486.82	19565.82	39831.98	2697.26
CrNV-03-682	Above Sehoo	Wash	1387.13	1676.46	10830.78	33046.79	436.96
CrNV-03-683	Historic-Sehoo	Lake	1326.32	1602.70	6542.47	31483.72	5233.57
CRNV-03-685	Above Sehoo	Wash	1374.6	3327.22	12464.45	34149.62	77.97
CrNV-03-7011	Above Sehoo	Wash	1470.66	13649.79	23129.82	28342.11	369.10
CrNV-03-8522	Above Sehoo	Wash	1412.75	13510.88	24459.48	29506.16	413.54
CRNV-03-8536	Above Sehoo	Wash	1549.11	14102.05	19297.31	24881.73	116.39
CRNV-03-8539	Above Sehoo	Wash	1536	14055.69	19782.91	25331.45	90.83
CRNV-31-3583	Below Historic	Wash	1240.91	11735.48	18157.72	14273.17	109.94
CRNV-32-3407	Above Sehoo	Wash	1670.3	9100.46	18420.15	42538.90	0.21
CRNV-32-3443	Above Sehoo	Wash	1569.18	7109.34	13849.88	31703.10	40.66
CRNV-32-3444	Above Sehoo	Wash	1538.28	6758.54	13699.93	31857.24	79.77
CRNV-32-3454	Above Sehoo	Wash	1715.66	6716.00	15721.83	39000.60	100.31
CRNV-32-3758	Above Sehoo	Wash	1712.98	9840.93	19143.33	43304.92	64.41
CRNV-32-3760	Above Sehoo	Wash	2200.66	13934.64	22813.51	47682.20	103.54
CrNV-32-3872	Historic-Sehoo	Lake	1314.16	629.97	4270.27	26364.86	821.12

Table C.2. Continued

Sites	Elevation Level	Closest primary landform	Elevation	Distance to Shoreline (m)	Distance to Holocene Shoreline (m)	Distance to Walker River Channel (m)	Distance to Wash (m)
CRNV-32-3874	Above Sehoo	Wash	1360.07	2752.92	11721.99	33110.13	192.57
CRNV-32-3875	Above Sehoo	Wash	1359.84	3049.78	12042.52	33397.45	148.98
CRNV-32-4603	Above Sehoo	Wash	2109.22	18198.90	19544.88	39182.59	113.16
CrNV-32-4752	Below Historic	Lake	1208.64	162.60	162.60	6997.10	6754.56
CRNV-32-5187	Above Sehoo	Wash	1427.99	5805.32	13005.17	38914.64	84.72
Walk-01	Historic-Sehoo	Wash	1328.14	54.47	377.68	7234.45	34.80
Walk-02	Historic-Sehoo	Wash	1318.67	519.47	929.08	14625.34	209.33
Walk-03	Below Historic	Lake	1238.53	298.70	298.70	2383.74	10548.62
Walk-04	Below Historic	Lake	1238.37	237.01	237.01	2399.12	10688.82
Walk-05	Below Historic	Lake	1239.36	551.11	551.11	2902.04	10882.74
Walk-06	Below Historic	Lake	1238.01	320.52	320.52	2732.43	10974.68
Walk-07	Below Historic	Lake	1237.45	172.46	172.46	2537.65	10913.75
Walk-08	Below Historic	Lake	1237.9	229.34	229.34	2484.31	10776.38
Walk-10	Below Historic	Lake	1235.55	102.62	102.62	2246.05	10654.18
Walk-11	Below Historic	Lake	1238.64	357.02	357.02	2661.25	10825.99
Walk-13	Below Historic	Lake	1233.13	6.60	6.60	2460.83	11034.08
Walk-14	Below Historic	Lake	1238.07	253.31	253.31	2781.70	11103.72
Walk-15	Below Historic	Lake	1237.51	219.86	219.86	2776.41	11216.84
Walk-16	Below Historic	Lake	1239.32	609.48	609.48	1098.57	10215.20
Walk-17	Below Historic	Lake	1238.56	448.16	448.16	655.00	10162.13
Walk-18	Below Historic	Lake	1238.79	479.25	479.25	594.32	10124.44
Walk-19	Below Historic	Lake	1238.3	419.97	419.97	449.29	10204.96
Walk-21	Below Historic	Lake	1236.67	352.39	352.39	993.48	10457.28

Table C.2. Continued

Sites	Elevation Level	Closest primary landform	Elevation	Distance to Shoreline (m)	Distance to Holocene Shoreline (m)	Distance to Walker River Channel (m)	Distance to Wash (m)
Walk-22	Below Historic	Lake	1237.34	503.00	503.00	1101.15	10371.03
Walk-23	Below Historic	Lake	1236.86	278.48	278.48	1349.03	10476.32
Walk-24	Below Historic	Lake	1237.34	241.03	241.03	687.53	10383.51
Walk-25	Below Historic	Lake	1238.34	429.42	429.42	2728.99	10814.53
Walk-26	Historic-Sehoo	Wash	1321.71	133.59	371.80	6527.38	57.77
Walk-27	Below Historic	Lake	1236.38	355.29	355.29	1042.64	10517.67
Walk-28	Below Historic	River	1225.77	595.85	595.85	184.82	11964.45
Walk-29	Below Historic	River	1222.95	1276.87	1276.87	265.09	12592.97
Walk-30	Below Historic	River	1223.08	1316.30	1316.30	285.62	12633.17
Walk-31	Below Historic	River	1224.13	1348.70	1348.70	293.11	12661.15
Walk-32	Below Historic	River	1223.44	1200.67	1200.67	185.22	12530.30
Walk-33	Below Historic	River	1224	980.14	980.14	123.70	12359.28
Walk-34	Below Historic	River	1219.12	1425.56	1425.56	12.74	13196.55
Walk-35	Below Historic	River	1219.59	1532.25	1532.25	20.73	13317.21
Walk-36	Below Historic	River	1210.92	779.17	779.17	103.58	9407.27
Walk-37	Below Historic	River	1213.33	930.62	930.62	112.68	9991.19
Walk-38	Below Historic	River	1214.1	1083.18	1083.18	141.84	10091.54
Walk-39	Below Historic	River	1217.41	1111.18	1111.18	2.21	11794.99
Walk-40	Below Historic	River	1216.89	1167.48	1167.48	14.84	11620.41
Walk-41	Below Historic	River	1217.36	1018.29	1018.29	32.44	11166.47

APPENDIX D

R SCRIPT

Note: all script below may be directly entered into an R script editor and then run in R if the appropriate tables are provided.

D.1. R script for Age Component by Landscape Tests

```
#The code below runs chi-square for age components by landforms

AgeLand<-read.csv("AgeLand.csv", row.names=1)
View(AgeLand)
AgeLandChi<-chisq.test(AgeLand)
AgeLandChi
print(AgeLandChi$expected, digits=3)

#The code below runs fisher's exact test for age components by landforms

AgeLandFis <- fisher.test(AgeLand)
AgeLandFis

#The code below runs kruskal wallis H for age components by elevation ranges

AgeElev<-read.csv("AgeElev.csv")
View(AgeElev)
kruskal.test(ElevRank ~ Age, AgeElev)
dunnTest(ElevRank ~ Age, data=AgeElev, method = "hs")
```

D.2. R script for Tests Comparing Descriptive Variables by Age and Landscape

```
#The code below runs chi-square for tool class by landform categories

TlClsLand<-read.csv("ToolClass_Land.csv", row.names=1)
View(TlClsLand)
TlClsLandChi<-chisq.test(TlClsLand)
TlClsLandChi
print(TlClsLandChi$expected, digits=3)

#The code below runs kruskal wallis for tool class by Elevation Rank
```

```
TlClsElev<-read.csv("ToolClass_Elev.csv")
View(TlClsElev)
kruskal.test(ElevRank ~ ToolClass, TlClsElev)
dunnTest(ElevRank ~ ToolClass, data=TlClsElev, method = "hs")

#The code below runs kruskal wallis for tool class by Age Rank

TlClsAge<-read.csv("ToolClass_Age.csv")
View(TlClsAge)
kruskal.test(AgeRank ~ ToolClass, TlClsAge)
dunnTest(AgeRank ~ ToolClass, data=TlClsAge, method = "hs")
```

D.3. R script for Tests Comparing Production Categories by Age and Landscape

```
# This code runs Mann-Whitney test for formal/informal tools vs. Age Rank

FIAge<-read.csv("Age_FI.csv")
View(FIAge)
wilcox.test(AgeRank ~ ToolType, FIAge)

#The following code runs chi-square for formal/informal count categories by landform

LandFI <- read.csv("Land_Chi_F-I.csv", row.names = 1)
View(LandFI)
LandFIChi <- chisq.test(LandFI)
LandFIChi
print(LandFIChi$expected, digits = 3)

#This code runs Mann-Whitney U for Formal/Informal counts by elevation

ElevFI <- read.csv("Elev_FI.csv")
View(ElevFI)
wilcox.test(Elev_Rank ~ Tool_Type, ElevFI)
```

D.4. R script for Tests Comparing Reduction Categories by Age and Landscape

```
#This code below runs Mann-Whitney test for lithic tools and cores vs. Age Ranks

TCAge<-read.csv("Age_TC.csv")
View(TCAge)
wilcox.test(AgeRank ~ ToolType, TCAge)

#The following code runs chi-square for flaked tool/core count categories by landform
```

```
LandTC <- read.csv("Land_Chi_TC.csv", row.names = 1)
View(LandTC)
LandTCChi <- chisq.test(LandTC)
LandTCChi
print(LandTCChi$expected, digits = 3)

#This code runs Mann-Whitney U Flaked Tool/Core counts by elevation

ElevTC <- read.csv("Elev_TC.csv")
View(ElevTC)
wilcox.test(Elev_Rank ~ Art_Type, ElevTC)
```

D.5. R script for Tests Comparing Task Categories by Age and Landscape

```
#The code below runs chi-square for Task Activites by landform categories

TaskLand<-read.csv("Tasks_Land.csv", row.names=1)
View(TaskLand)
TaskLandChi<-chisq.test(TaskLand)
TaskLandChi
print(TaskLandChi$expected, digits=3)

#The code below runs kruskal wallis H for Task Activities by Elevation Rank

TaskElev<-read.csv("Tasks_Elev.csv")
View(TaskElev)
kruskal.test(ElevRank ~ Task, TaskElev)
dunnTest(ElevRank ~ Task, data=TaskElev, method = "hs")

#The code below runs kruskal wallis H for Task Actitivies by Age Rank

TaskAge<-read.csv("Tasks_Age.csv")
View(TaskAge)
kruskal.test(AgeRank ~ Task, TaskAge)
dunnTest(AgeRank ~ Task, data=TaskAge, method = "hs")
```

D.6. R script for Tests Comparing Age and Landscape by Site Type

```
#The code below runs Kruskal Wallis H for Age Categories by Type Count Rank

TypeAge<-read.csv("TypeAge.csv")
View(TypeAge)
```

```
kruskal.test(TypeRank ~ Age, TypeAge)
dunnTest(TypeRank ~ Age, data=TypeAge, method = "hs")

#This code provides Kruskal Wallis Tests comparing artifact type count ranks and Landform categories

TypeSite <- read.csv("TypeCnt.csv")
View(TypeSite)
kruskal.test (ArtRanking ~ All.Landscapes, TypeSite)
dunnTest(ArtRanking ~ All.Landscapes, data = TypeSite, method = "hs")

#This code provides Kruskal Wallis Tests comparing artifact type count ranks and Elevation categories

TypeSiteA <- read.csv("AllTypeCnt.csv")
View(TypeSiteA)
kruskal.test(ArtRanking ~ Elevation.Level, TypeSiteA)
dunnTest(ArtRanking ~ Elevation.Level, data = TypeSiteA, method = "hs")
```

APPENDIX E

STATISTICAL RESULTS

E.1. Age Components on the Landscape

Table E.1. Chi-square test comparing age component counts by landform types.

Landform Type		Walker Lake Age Components: Paleoindian	Early-Mid Archaic	Late Archaic	Late Prehistoric	Total	Mean Rank
Lake	Count	4	3	4	12	23	
	Expected Count	3.9	6.4	4.9	7.8	23.0	**27.95**
	% Column Total	50.0	23.1	40.0	75.0	48.9	
River	Count	0	3	3	0	6	
	Expected Count	1.0	1.6	1.3	2.1	6.0	**20.75**
	% Column Total	0.0	23.1	30.0	0.0	12.8	
Wash	Count	4	7	3	4	18	
	Expected Count	3.1	5.0	3.8	6.1	16.0	**20.03**
	% Column Total	50.0	53.8	30.0	25.0	38.3	
Total	Count	8	13	10	16	47	
	Expected Count	8.0	13.0	10.0	16.0	47.0	
	% of Total	17.0	27.7	21.3	34.0	100.0	
Chi-square: $\chi2=12.661$, df=6, p=0.0487							
Fisher's Exact Test: p=0.0404							
Kruskal Wallis H: $\chi2=4.067$, df=2, p=0.1309							

Table E.2. Kruskal Wallis H test comparing age components to elevation ranges.

Site Age	Walker Lake Elevation Range: Below Historic Highstand	Historic-Sehoo Highstands	Above Sehoo Highstand	n	Mean Rank
Paleoindian	2 (7.7%)	5 (38.5%)	1 (12.5%)	8	29.44
Early-Middle Archaic	6 (23.1%)	3 (23.1%)	4 (50.0%)	13	22.04
Late Archaic	7 (26.9%)	1 (7.7%)	2 (25.0%)	10	21.45
Late Prehistoric	11 (42.3%)	4 (30.8%)	1 (12.5%)	16	20.25
Total Sites	26	13	8	47	
Kruskal Wallis H: $\chi^2=4.376$, df=3, p=0.2236					

E.2. Descriptive Statistics Dunn Tests

Table E.3. Dunn Test showing p-values between artifact classes compared by age components.

Comparisons	Z	P-Unadjusted	P-Adjusted
Biface-Cobble Tool	-0.424	0.6718	0.9646
Biface-Core	-1.781	0.0750	0.5757
Cobble Tool-Core	-0.174	0.8617	0.9809
Biface-Ground Stone	-3.232	0.0012	0.0171
Cobble Tool-Ground Stone	-0.788	0.4306	0.9659
Core-Ground Stone	-1.499	0.1339	0.7625
Biface-Point	0.459	0.6466	0.9844
Cobble Tool-Point	0.557	0.5772	0.9865
Core-Point	2.111	0.0348	0.3462
Ground Stone-Point	3.493	0.0005	0.0071
Biface-Uniface	-0.931	0.3516	0.9688
Cobble Tool-Uniface	0.136	0.8920	0.8920
Core-Uniface	0.895	0.3816	0.9654
Ground stone-Uniface	2.366	0.0180	0.2103
Point-Uniface	-1.319	0.1873	0.8453

Table E.4. Dunn test showing p-values between artifact classes compared by elevation ranges.

Comparisons	Z	P-Unadjusted	P-Adjusted
Biface-Cobble Tool	0.871	0.3834	0.9661
Biface-Core	3.922	<0.0001	0.0011
Cobble Tool-Core	0.411	0.6810	0.9676
Biface-Ground Stone	4.258	<0.0001	0.0003
Cobble Tool-Ground Stone	0.501	0.6166	0.9917
Core-Ground Stone	0.241	0.8094	0.9637
Biface-Point	3.436	0.0006	0.0071
Cobble Tool-Point	0.229	0.8191	0.8191
Core-Point	-0.500	0.6174	0.9786

Table E.4. Continued

Comparisons	Z	P-Unadjusted	P-Adjusted
Ground Stone-Point	-0.751	0.4527	0.9731
Biface-Uniface	5.948	<0.0001	<0.0001
Cobble Tool-Uniface	0.920	0.3576	0.9710
Core-Uniface	1.431	0.1525	0.8089
Ground stone-Uniface	1.191	0.2334	0.9086
Point-Uniface	1.992	0.0464	0.4069

E.3. Tool Reduction Statistics

Table E.5. Mann-Whitney U test comparing primary and secondary reduction activities by age components.

Reduction Activities	Walker Lake Age Components				n	Mean Rank
	Paleoindian	Early-Middle Archaic	Late Archaic	Late Prehistoric		
Secondary Reduction	33 (91.7%)	26 (81.3%)	14 (93.3%)	52 (76.5%)	125	73.20
Primary Reduction	3 (8.3%)	6 (18.7%)	1 (6.7%)	16 (23.5%)	26	89.48
Total Artifacts	36	32	15	68	151	
Mann Whitney U: W=1947.5, p=0.0921						

Table E.6. Chi-square test comparing primary and secondary reduction by landforms.

Reduction Strategies		Lake	River	Wash	Total
Secondary Reduction	Count	141	34	120	295
	Expected Count	148.3	32.6	114.1	295.0
	% Column Total	77.5	85.0	85.7	81.5
Primary Reduction	Count	41	6	20	67
	Expected Count	33.7	7.4	25.9	67.0
	% Row Total	22.5	15.0	14.3	18.5

Table E.6. Continued

Reduction Strategies		Lake	River	Wash	Total
Total	**Count**	182	40	140	362
	Expected Count	182.0	40.0	140.0	362.0
	% of Total	50.3	11.0	18.5	100.0
Chi-Square: $\chi2$=3.9307, df=2, p=0.1401					

Table E.7. Mann-Whitney U test comparing Lithic tool and core counts by elevation ranges.

Reduction Activities	Walker Lake Elevation Range			n	Mean Rank
	Below Historic Highstand	**Historic-Sehoo Highstands**	**Above Sehoo Highstand**		
Secondary Reduction	145 (77.1%)	78 (91.8%)	74 (81.3%)	297	186.28
Primary Reduction	43 (22.9%)	7 (8.2%)	17 (18.7%)	67	165.72
Total Artifacts	188	85	91	364	
Mann Whitney U: W=8825.5, p=0.1138					

E.4. Tool Production Statistics

Table E.8. Mann-Whitney U test comparing formal and informal tool production by age components.

Tool Production	Walker Lake Age Components				n	Mean Rank
	Paleoindian	**Early-Middle Archaic**	**Late Archaic**	**Late Prehistoric**		
Formal	26 (78.8%)	21 (80.8%)	12 (85.7%)	34 (65.4%)	93	60.21
Informal	7 (21.2%)	5 (19.2%)	2 (14.3%)	18 (34.6%)	32	71.11
Total Artifacts	33	26	14	52	125	
Mann-Whitney U: W=1216.5, p=0.1063						

Table E.9. Chi-square test comparing formal and informal tool production by landform type.

Tool Production		Lake	River	Wash	Total
Formal	Count	89	26	100	215
	Expected Count	102.8	24.8	87.5	215.1
	% Column Total	63.1	76.5	83.3	72.9
Informal	Count	52	8	20	80
	Expected Count	38.2	9.2	32.5	79.9
	% Column Total	36.9	23.5	16.7	27.1
Total	Count	141	34	120	295
	Expected Count	141.0	34.0	120.0	295.0
	% of Total	47.8	11.5	40.7	100.0
Chi-Square: χ2=13.651, df=2, p=0.00109					

Table E.10. Mann-Whitney U test comparing formal and informal tool production by elevation ranges.

Tool Production	Walker Lake Elevation Range			n	Mean Rank
	Below Historic Highstand	Historic-Sehoo Highstands	Above Sehoo Highstand		
Formal	87 (60.0%)	67 (85.9%)	61 (82.4%)	215	160.94
Informal	58 (40.0%)	11 (14.1%)	13 (17.6%)	82	117.68
Total Artifacts	145	78	74	297	
Mann-Whitney U: W=11383, p<0.0001					

E.5. Task Activity Statistics

Table E.11. Kruskal Wallis H test comparing task activities by age components.

Task Activities	Walker Lake Age Component				n	Mean Rank
	Paleoindian	Early-Mid Archaic	Late Archaic	Late Prehistoric		
Hunting	25 (75.8%)	19 (76.0%)	11 (61.1%)	33 (50.8%)	88	64.07
Initial Processing	8 (24.2%)	6 (24.0%)	3 (16.7%)	18 (27.7%)	35	73.61

Table E.11. Continued

Task Activities	Paleoindian	Early-Mid Archaic	Late Archaic	Late Prehistoric	n	Mean Rank
Intensive Processing	0 (0%)	0 (0%)	4 (22.2%)	14 (21.5%)	18	99.78
Total Artifacts	33	25	18	65	141	
Kruskal Wallis H: $\chi2$=13.167, df=2, p-value=0.0014						

Table E.12. Dunn test showing p-values between task activities compared by age components.

Comparison	Z	P-Unadjusted	P-Adjusted
Hunting-Initial Processing	-1.245	0.2132	0.2132
Hunting-Intensive Processing	-3.599	0.0003	0.0009
Initial-Intensive Processing	-2.352	0.0157	0.0370

Table E.13. Chi-square test comparing task activities by landform type.

		Walker Lake Landform Types			
Task Activities		**Lake**	**River**	**Wash**	**Total**
Hunting	**Count**	80	24	98	202
	Expected Count	94.8	31.4	75.8	202.0
	% Column Total	47.3	42.8	72.6	56.1
Initial Processing	**Count**	58	10	20	88
	Expected Count	41.3	13.7	33.0	88.0
	% Column Total	34.3	17.9	14.8	24.4
Intensive Processing	**Count**	31	22	17	70
	Expected Count	32.9	10.9	26.2	70.0
	% Column Total	18.4	39.3	12.6	19.5
Total	**Count**	169	56	135	360
	Expected Count	169.0	56.0	135.0	360.0
	% of Total	46.9	15.6	37.5	100.0
Chi-Square: $\chi2$=38.167, df=4, p-value=<0.0001					

Table E.14. Kruskal Wallis H test comparing task activities by elevation ranges.

Task Activities	Walker Lake Elevation Range			n	Mean Rank
	Below Historic Highstand	Historic-Sehoo Highstands	Above Sehoo Highstand		
Hunting	77 (41.4%)	65 (71.4%)	60 (70.6%)	202	205.34
Initial Processing	65 (34.9%)	13 (14.3%)	12 (14.1%)	90	143.71
Intensive Processing	44 (23.7%)	13 (14.3%)	13 (15.3%)	70	161.29
Total Artifacts	186	91	85	362	
Kruskal Wallis H: χ2=29.729, df=2, p-value=<0.0001					

Table E.15. Dunn test showing p-values between task activities compared by elevation ranges.

Comparison	Z	P-Unadjusted	P-Adjusted
Hunting-Initial Processing	5.085	<0.0001	<0.0001
Hunting-Intensive Processing	3.321	0.0009	0.0018
Initial-Intensive Processing	-1.153	0.2488	0.2488

E.6. Site Type Statistics

Table E.16. Kruskal Wallis H test comparing age components by site types.

Elevation Range	Number of Walker Lake Basin Sites with			n	Mean Rank
	Single Activity	Moderate Activities	Diverse Activities		
Paleoindian	1 (20.0%)	3 (60.0%)	1 (20.0%)	5	8.30
Early-Mid Archaic	1 (20.0%)	0	4 (80.0%)	5	14.00
Late Archaic	0	1 (33.3%)	2 (66.7%)	3	13.83
Late Prehistoric	1 (11.1%)	4 (44.4%)	4 (44.4%)	9	11.11
Total Sites	3	8	11	22	
Kruskal Wallis H: χ^2=2.875, df=3, p=0.4113					

Table E.17. Dunn test showing p-values between site age components compared by site types.

Comparisons	Z	p-unadjusted	p-adjusted
E/M Archaic-Late Archaic	0.038	0.9692	0.9692
E/M Archaic-Late Prehistoric	0.878	0.3802	0.8524
Late Archaic-Late Prehistoric	0.692	0.4890	0.7389
E/M Archaic-Paleoindian	1.527	0.1267	0.5566
Late Archaic-Paleoindian	1.284	0.1992	0.6707
Late Prehistoric-Paleoindian	0.854	0.3931	0.7765

Table E.18. Kruskal Wallis H test comparing landform types by site types.

Landform	Number of Walker Lake Basin Sites with				Mean
Types	Single Activity	Moderate Activities	Diverse Activities	n	Rank
Lake	14 (42.4%)	7 (21.2%)	12 (36.4%)	33	63.67
River	7 (43.75%)	5 (31.25%)	4 (25.0%)	16	60.31
Wash	38 (64.4%)	15 (25.4%)	6 (10.2%)	59	47.80
Total Sites	59	27	22	108	
Kruskal Wallis H: χ^2=7.479, df=2, p=0.0238					

Table E.19. Dunn test showing p-values between site landform types compared by site types.

Comparisons	Z	p-unadjusted	p-adjusted
Lake-River	0.390	0.6966	0.6966
Lake-Wash	2.585	0.0097	0.0289
River-Wash	1.578	0.1159	0.2183

Table E.20. Kruskal Wallis H test comparing site elevation ranges by site types.

Elevation Range	Number of Walker Lake Basin Sites with Single Activity	Moderate Activities	Diverse Activities	n	Mean Rank
Below Historic	19 (46.3%)	8 (19.5%)	14 (34.2%)	41	62.98
Historic-Sehoo	7 (35.0%)	9 (45.0%)	4 (20.0%)	20	64.50
Above Sehoo	35 (71.4%)	10 (20.4%)	4 (8.2%)	49	45.57
Total Sites	61	27	22	110	
Kruskal Wallis H: χ^2=10.649, df=2, p=0.0049					

Table E.21. Dunn test showing p-values between site elevation ranges compared by site types.

Comparisons	Z	p-unadjusted	p-adjusted
Above Sehoo-Below Historic	-2.870	0.0041	0.0123
Above Sehoo-Historic/Sehoo	-2.490	0.0128	0.0254
Below Historic-Historic/Sehoo	-0.195	0.8453	0.8453