

HUMAN PALEOECOLOGY IN THE HIGH DESERT:
12,600 YEARS OF HUMAN-PLANT DYNAMICS IN THE NORTHERN GREAT BASIN,
OREGON, USA

A Dissertation

by

KATELYN NEEDHAM MCDONOUGH

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Chair of Committee,	Ted Goebel
Committee Members,	Heather Thakar
	Michael Waters
	Thomas Craig
Head of Department,	Darryl de Ruiter

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ABSTRACT

This dissertation investigates the dynamics of climate and culture in the Great Basin of North America using multiproxy data derived from combustion features, coprolites, and sediment cores from Connley Caves and Paulina Marsh in central Oregon.

This research is divided into three articles united by the theme of human paleoecology, beginning with a paleoethnobotanical analysis of five combustion features from Pleistocene and Early Holocene components at Connley Cave 5 in central Oregon. The robust archaeobotanical assemblages produced in this study reaffirms the inclusion of plants in the Paleoindian food economy and supports the idea that groups using Western Stemmed toolkits had broad-based diets. These data contribute to a growing body of research indicating that regionally adapted subsistence strategies were in place by at least the Younger Dryas and that groups using Western Stemmed toolkits may have incorporated a wider range of plants into their diets earlier than groups elsewhere. Explaining the appearance of seemingly low ranked resources in the emerging Paleoindian plant-food economy may require consideration of nutritional variables other than net caloric returns.

Next, my multiproxy coprolite analysis reveals aspects of diet, seasonal mobility, and health of foragers who visited Connley Caves between 5700 and 3200 calendar years ago (cal BP). Macrobotanical, palynological, and faunal constituents indicate that people foraged for a wide range of resources from both wetland and dryland habitats during the late summer and fall. One possible instance of parasitic infection reveals aspects of human health. These data strengthen the existing settlement-subsistence record in the northern Great Basin and provides pertinent information to the broader field of coprolite research.

Lastly, I present new data from five sediment cores that I obtained from Paulina Marsh. Palynological, sedimentological, and elemental data from core PAUL-2A reflect shifts in local hydrology and vegetation histories that contribute to the understanding of climate change in the northern Great Basin. These data constitute the first Early Holocene pollen record from the Fort Rock Basin and establish a framework for future work in Paulina Marsh.

Cumulatively, this dissertation refines our understanding of forager food economies and the dynamics between climate, vegetation, and cultural practices.

DEDICATION

To Vaughn M. Bryant, Jr. who taught me to appreciate the little things.

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Professor Vaughn M. Bryant, Jr. of the Department of Anthropology at Texas A&M University served as committee co-chair until he passed away on January 30, 2021.

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TABLE OF CONTENTS

	Page
ABSTRACT.....	ii
DEDICATION.....	iv
ACKNOWLEDGEMENTS.....	v
CONTRIBUTORS AND FUNDING SOURCES	ix
TABLE OF CONTENTS.....	xii
LIST OF FIGURES.....	xv
LIST OF TABLES	xvii
CHAPTER I INTRODUCTION.....	1
1.1. Research Themes	2
1.1.1. Foraging Strategies and the Role of Plants in Great Basin Food Economies.....	2
1.1.2. Paleoenvironmental Histories of the Great Basin.....	5
1.2. Study Area	6
1.2.1. Connley Caves	9
1.2.2. Paulina Marsh	10
1.3. Research Structure	10
1.4. References.....	13
CHAPTER II EXPANDING PALEOINDIAN DIET BREADTH: PALEOETHNOBOTANY OF CONNLEY CAVE 5, OREGON, USA.....	26
2.1. Pleistocene Subsistence in Temperate North America.....	29
2.2. Connley Caves Site Background and Environmental Setting	37
2.2.1. Physiographic and Environmental Setting.....	38
2.3. Materials and Methods.....	39
2.3.1. Feature Descriptions	41
2.3.2. Radiocarbon Dating.....	42
2.3.3. Archaeobotanical Analysis	43
2.3.4. Quantification and Statistics	46
2.4. Results.....	48
2.4.1. Stratigraphy.....	48
2.4.2. Feature Descriptions	50
2.4.3. Radiocarbon Dating.....	51
2.4.4. Archaeobotanical Analysis	52
2.5. Feature Interpretations	59
2.5.1. Feature 1 (~12,500 cal BP).....	64
2.5.2. Feature 2 (~12,000- 11,800 cal BP).....	64
2.5.3. Feature 3 (~11,800 cal BP).....	66
2.5.4. Feature 4 (~11,500 cal BP).....	67

2.5.5. Feature 5 (~10,200 cal BP).....	68
2.6. Discussion.....	68
2.6.1. Paleoindian Plant Use at Connley Caves.....	68
2.6.2. Contribution to the Paleoindian Subsistence Record.....	71
2.6.3. Implications for Settlement-Subsistence Models Based on Caloric Optimization.....	76
2.7. Conclusions.....	82
2.8. References.....	85

CHAPTER III MIDDLE HOLOCENE MENUS: DIETARY RECONSTRUCTION FROM COPROLITES AT THE CONNLEY CAVES, OREGON, USA 110

3.1. Environmental and Archaeological Context.....	112
3.1.1. Environmental Setting	112
3.1.2. Regional Context and Cultural Chronology	113
3.2. Site Background.....	115
3.3. Materials and Methods.....	118
3.3.1. Laboratory Procedures and Analysis	120
3.4. Results.....	124
3.4.1. Macrofossils.....	127
3.4.2. Microfossils	129
3.4.3. Parasites	132
3.4.4. Other Constituents	134
3.4.5. Assessment of Human Origin.....	134
3.5. Discussion.....	135
3.5.1. Diet	135
3.5.2. Settlement Subsistence	142
3.5.3. Parasites	145
3.5.4. Future Directions	146
3.6. Conclusion	147
3.7. References.....	148

CHAPTER IV HOLOCENE VEGETATION HISTORY AND CLIMATE OF CENTRAL OREGON: THE EMERGING RECORD FROM PAULINA MARSH, OREGON..... 163

4.1. Climate Change and Human Paleoecology in the Northern Great Basin.....	167
4.2. Study Area	170
4.2.1. Hydrologic History	174
4.2.2. Research Questions.....	176
4.3. Methods	177
4.4. Results.....	182
4.4.1. Age-Depth Model and Sedimentary Units for Core PAUL-2A	182
4.4.2. Palynological Record.....	186
4.4.3. Initial Radiocarbon Dating of other Cores.....	190
4.5. Interpretations and Discussion.....	193
4.5.1. Geomorphologic History	194
4.5.2. Taphonomy of Pollen Record.....	195
4.5.3. Vegetation History.....	197
4.5.4. Comparison to Other Pollen Records	201

4.5.5. Comparison to Human Palaeoecological Models in the Fort Rock Basin.....	205
4.5.6. Expression of Global Climatic Events.....	209
4.6. Conclusions.....	210
4.7. References.....	213
CHAPTER V CONCLUSIONS	228
5.1. Paleoethnobotanical Perspectives on Paleoindian Lifeways	228
5.2. Settlement-Subsistence and Dietary Datasets during the Holocene	230
5.3. Paulina Marsh’s Emerging Paleoclimatic Record	232
5.4. Future Studies	235
5.4.1. Human Nutrition and Foraging Choices.....	235
5.4.2. Paleoenvironmental Research.....	237
5.5. Conclusion	237
5.6. References.....	239
APPENDIX A SUPPLEMENTARY DATA FOR CAVE 5 COMBUSTIONS FEATURES, STRATIGRAPHY, AND RADIOCARBON SAMPLES	240
APPENDIX B CONNLEY CAVES COPROLITE COUNTS.....	250
APPENDIX C CODE FOR AGE DEPTH MODEL IN OXCAL	251
APPENDIX D POLLEN GRAIN AND TRACER SPORE ABSOLUTE COUNTS, TOTALS, AND POLLEN CONCENTRATION VALUES FOR EACH PAUL-2A SAMPLE.....	253

LIST OF FIGURES

	Page
Figure 2.1. Map displaying location of Connley Caves and Paleoindian sites with subsistence data older than 11,700 cal BP	29
Figure 2.2. Top Panel: View of the Connley Caves looking north-northeast. See person in blue standing at eastern edge of Cave 5 excavation block for scale. Middle Panel: Location of the site within the Fort Rock Basin showing proximity to Paulina Marsh. Bottom Panel: View looking south from the top of the Connley Caves toward Paulina Marsh with Hager Mountain in the distance	36
Figure 2.3. Planview of Connley Cave 5 (2014 to 2019) block showing excavation grid and the locations of features and column sample discussed in the text.....	40
Figure 2.4. Violin plot of total charred seed density (average NISP per liter) by sample type. ...	48
Figure 2.5. Perspective view of the Cave 5 excavation block showing features 1 through 4.....	49
Figure 2.6 . Stratigraphic interpretation of the west profile of Unit 25 with corresponding lithostratigraphic units (LU)	53
Figure 2.7. Examples of seeds (a-c, e-w) and other macrobotanicals (d, w) recovered from combustion features	54
Figure 2.8. Cluster dendrogram of features using NISP of seeds considered “probable” and “possible” dietary constituents.....	59
Figure 2.9. Summary of hearth contents.....	63
Figure 2.10. Examples of other hearth constituents: (a) bone eyed needle (2556-2530); (p) bone eyed needle eye (2556-1150); (c) charred and fragmented Amaranthaceae seeds; (d) fish vertebrae from Feature 4; (e) example of charred starchy tissue; (f) eggshell fragments	65
Figure 3.1. Map showing location of the Connley Caves and other sites discussed in the text .	111
Figure 3.2. Plan view of the Connley Caves with an inlay of artifacts coprolites found in the latrine area between depths of 1357.70 and 1358.15 meters above sea level.....	117
Figure 3.3. Macrobotanical remains found in coprolites	128
Figure 3.4. Pollen diagram depicting the relative frequency and total pollen concentration values for each coprolite in the C Series.....	130
Figure 3.5. Selected pollen grains recovered from coprolites	131
Figure 3.6. Parasites found in coprolites.....	133
Figure 3.7. Cluster analysis of primary coprolite constituents from Connley Cave.....	140

Figure 4.1. Map of the Fort Rock Basin showing location of Paulina Marsh and archaeological sites discussed in the text	165
Figure 4.2. Location of sediment cores from Paulina Marsh.....	166
Figure 4.3. Lidar imagery of coring locations in Paulina Marsh	169
Figure 4.4. Top: Looking south across Paulina Marsh from above the Connley Caves toward Hagar Mountain. Bottom: Looking north toward Connley Caves 6, 5, and 4.....	173
Figure 4.5. Coring in Site 2: (a) area just north of site 2A, arrow points to coring location; (b) coring with modified Livingstone in 2018; (c) view of marsh looking north-northeast; (d) coring with Geoprobe in 2019.....	174
Figure 4.6. Age-depth model output for PAUL-2A.....	183
Figure 4.7. Sedimentological and soil characterization data obtained from Core 2A	184
Figure 4.8. Pollen percentage diagram for PAUL-2A showing selected pollen taxa, pollen concentration values (PCV), pollen zones, and lithostratigraphic units	188
Figure 4.9. Ratio of pollen abundance between taxa	189
Figure 4.10. Examples of herbaceous shrubs and grass pollen identified in PAUL-2A	191
Figure 4.11. Examples of arboreal pollen identified in PAUL-2A.....	192
Figure 4.12. Locations of pollen cores and profiles discussed in the text shown within an outline of the northern Great Basin.....	203
Figure 4.13. Comparison of vegetation proxy data from Paulina Marsh to northern Great Basin Cultural Periods, regional paleoenvironmental records, and global climatic events.....	207

LIST OF TABLES

	Page
Table 2.1. Radiocarbon ages on <i>Artemisia</i> charcoal from cultural features in Connley Cave 5	43
Table 2.2. Feature sample data	55
Table 2.3. Names, traditional uses, plant communities (PC), seasonal availability, and dietary association of taxa from features	61
Table 2.4. Comparison of macro- and micronutrients of traditionally foraged plant and animal taxa	81
Table 3.1. Radiocarbon ages from coprolites and associated materials for the middle to late Holocene transition at the Connley Caves	119
Table 3.2. Contents of Connley Cave coprolites	125
Table 3.3. Habitat type, seasonal availability, and ethnographic uses of plant taxa in Connley Cave coprolites.....	137
Table 3.4. Abundance quintile values of dietary constituents used in cluster analysis	141
Table 4.1. Radiocarbon ages from Paulina Marsh sediment cores	179

CHAPTER I

INTRODUCTION

This dissertation research integrates chronological frameworks, multiscalar subsistence data, and paleoenvironmental proxies to investigate the relationships between culture and climate since the late Pleistocene in the Great Basin region of North America. The unifying approach that links the following three chapters is human paleoecology—the study of interactions between people and their environment in the past. The composition of past landscapes and how foragers exploited them is fundamental to myriad aspects of hunger-gatherer anthropological research, including diet, health, mobility, social organization, material culture, and more. A primary obstacle to understanding these dynamics is the need for both fine-grained dietary and environmental proxy data. Such requirements are especially difficult to fulfill when investigating the role of plants, as taphonomic processes often lead to the underrepresentation of botanical remains in the archaeological record. In response to these issues, this project uses an integrative, multiproxy approach to develop dietary and paleoenvironmental records from a multicomponent rockshelter site and neighboring marshland in the northern Great Basin region of central Oregon.

The Connley Caves and Paulina Marsh present a unique and ideal opportunity to conduct a two-pronged study that combines archaeological and paleoenvironmental data to examine long-term patterns of climate change and cultural adaptations. The first prong focuses on dietary remains at Connley Caves where recent reinvestigation of the site uncovered multiple cultural components spanning from the terminal Pleistocene to the Late Holocene. To examine diachronic trends in foraging behavior, the role of plant foods, and seasonal mobility, I conducted a paleoethnobotanical analysis of five combustion features from the Paleoindian

components (ca. 12,500 to 10,200 calendar years ago [cal BP]) (Chapter II) and a multiproxy coprolite analysis from the Middle and Late Holocene components (ca. 5200 to 3200 cal BP) (Chapter III) of Connley Cave 5. The second prong uses palynological, geomorphological, and radiocarbon records from Paulina Marsh to reconstruct the environment in which people were foraging and to understand the timing of climatic shifts in the northern Great Basin (Chapter IV). Together, these data transform our view of human behavior at Connley Caves and provide unique perspectives on the complex interaction between people, plant communities, and climate, with implications for understanding human behavioral adaptations to changing environments through time.

1.1. Research Themes

1.1.1. Foraging Strategies and the Role of Plants in Great Basin Food Economies

This research broadly explores the relationship between people and their environment, with a focus on understanding the composition of past food economies and landscapes. Such relationships are especially critical in the Great Basin, which has undergone significant environmental shifts and where resource availability is seasonal and highly affected by climatic fluctuations. I focus my investigation of plant use and foraging practices on two temporal periods: the Pleistocene-Holocene transition, a time referred to as the Paleoindian period in North America, and the Middle-Late Holocene transition, a time known as the Bergen Period in the northern Great Basin (Jenkins, Connolly et al. 2004). Understanding subsistence during these time periods is important because it informs broader debates about foraging behavior, human adaptive strategies, and the initial settlement of North America.

Past and current research on Paleoindian food economies have been predominantly derived from faunal records (e.g., Cannon and Meltzer 2004; Gingerich and Kitchel 2015;

Haynes and Hutson 2013; Hill 2008; Lothrop 2016), severely limiting our understanding of plant exploitation and biasing our perceptions of early lifeways. Additionally, researchers developed the first models for Paleoindian subsistence and land use from Clovis, Folsom, and Plano tradition archaeological sites in the Great Plains and Southwest (Heizer and Baumhoff 1970; Kelly and Todd 1988; Surovell and Waguespack 2009). As such, they reflect the predominant subsistence strategies of those regions, particularly high mobility and specialized big-game hunting. Research from the last decade shows that humans were in the Great Basin and Columbia Plateau by at least Clovis times (ca. 13,200 to 12,700 cal BP), but employed different projectile technology known as the Western Stemmed Tradition (WST) (Davis et al. 2019; Jenkins et al. 2012; Shillito et al. 2020). Dietary remains from WST sites in the Great Basin deviate from traditional models developed to explain Paleoindian subsistence strategies elsewhere in North America. Some of the earliest archaeological assemblages in the Great Basin suggest that WST groups exploited a broad range of resources including a variety of mammals, fish, and insects (Cummings and Puseman 2003; Hockett 2007; Hockett et al. 2017; Jenkins et al. 2013, 2016; Kennedy 2018; Rhode and Louderback 2007). Though it is widely assumed that Paleoindian groups also utilized wild plant foods, very little direct dietary evidence is available to clarify taxonomic diversity and overall contribution to diet (Goebel et al. 2011:497).

The primary problem impeding our understanding of Pleistocene plant use is the small sample of well-dated, stratified contexts with preserved macrobotanical remains. Some of the most robust evidence of plant use during the Pleistocene comes from the Great Basin, where archaeobotanical assemblages have been recovered in association with WST tool technology at three sites: Paisley Caves in Oregon (Blong et al. 2020; Jenkins et al. 2016; Kennedy 2018), Bonneville Estates Rockshelter in Nevada (Rhode and Louderback 2007), and the Wishbone site

in Utah (Duke et al. 2018). Collectively, these sites suggest that at least some groups who lived in the Great Basin during the Younger Dryas (ca. 12,900 to 11,700 cal BP) incorporated a range of small seeds, cacti, roots, and fruits into their diets. The diversity of plant resources at those sites contrasts with economic plant remains from Pleistocene sites farther east, such as Shawnee Minisink in Pennsylvania (Dent 2007; Gingerich 2011, 2013) and Dust Cave in Alabama (Driskell 1996; Hollenbach 2007; Hollenbach and Walker 2010), where economic taxa are dominated by nuts and fruits. Additional archaeobotanical data from secure archaeological contexts are needed to clarify these patterns and to gain a more holistic perspective on Paleoindian lifeways.

Considerably more archaeobotanical data and other evidence of human foraging practices are available during the Bergen Period (ca. 6000 to 3000 cal BP); however, nearly all of those data are from open-air sites and very little is known about the role of rockshelters during that time. Similar to the Younger Dryas, the Bergen Period is characterized by cool temperatures, productive marshes, and lacustrine-focused settlement patterns (Aikens et al. 2011; Jenkins, Connolly et al. 2004). The emergence of multihousehold villages along lake and marsh margins coupled with upticks in cache pits, groundstone artifacts, and a diversity of trade items indicate increased sedentism and social complexity (Jenkins, Connolly et al., eds. 2004; Jenkins, Largaespada, et al. 2004). Jenkins (1994, 2004) has proposed that even as sedentism increased, groups still retained some degree of mobility. As such, archaeological data from temporary habitation sites or logistical stopovers are needed to clarify where people stayed while away from their hamlets and where they gathered foods for long term storage.

I contribute to the current view of foraging behavior during the Paleoindian and Bergen periods through my analysis of dietary proxy records and new radiocarbon ages from

previously unreported cultural components at the Connley Caves.

1.1.2. Paleoenvironmental Histories of the Great Basin

Great Basin archaeologists have long hypothesized that cultural changes are closely tied to environmental shifts, but our ability to disentangle those relationships is limited by the availability and quality of proxy records for paleoclimates. Current paleoecological records also suggest that the timing and intensity of environmental changes corresponding to globally recognized climatic shifts did not always occur uniformly across the Great Basin (e.g., Hudson et al. 2019; McGee et al. 2018; Lyle et al. 2012; Wigand and Rhode 2002), meaning that proxy records from one basin may not accurately reflect conditions in another basin, and locally refined paleoclimate records are needed to test proposed settlement-subsistence models. Robust paleoenvironmental records have been developed for some basins, particularly in areas of Nevada, Utah, and eastern California (Adams et al. 2008; Benson et al. 1990, 1998; Godsey et al. 2011; Goebel et al. 2011; Louderback and Rhode 2009; McGee et al. 2012; Oviatt et al. 2005, 2015; Reheis et al. 2014; Rhode 2000; Rhode and Madsen 1995; Wigand and Rhode 2002) but records are relatively sparse in the northern Great Basin. This is especially problematic in the northwestern-most drainage, the Fort Rock Basin, which is renowned for its archaeology (e.g., Aikens and Jenkins 1994; Bedwell 1970, 1973; Connolly et al. 2016; Helzer 2004; Jenkins, Connolly et al., eds. 2004; Jenkins et al. 2017; McDonough 2019; Rosencrance et al. 2019; Wingard 2001). The Fort Rock Basin lacks local paleoenvironmental records needed to fully contextualize those data.

Current regional vegetation histories in the northern Great Basin are primarily derived from high-elevation coring sites, such as Dead Horse Lake (2248 m), Fish Lake (2250 m), Wildhorse Lake (2565 m), and Bicycle Pond (1800 m) in Oregon and Lily Lake (2040 m) in

California (Mehring 1985; Minckley et al. 2007; Wigand and Rhode 2002). Attempts to obtain pollen records from lowland settings where foragers spent the majority of their time have suffered from issues of deflation and inadequate age control (Cohen et al. 2000; Cummings 2001; Hansen 1947), and those that were successful are lacking significant portions of the Holocene (e.g., Paisley Caves [Beck et al. 2018; Saban 2015]; Diamond Pond [Wigand 1987]). While these vegetation histories provide important paleoenvironmental information, more high-resolution lowland vegetation histories are needed to test proposed settlement, subsistence, and mobility models that rely on the availability of water and food resources.

1.2. Study Area

Connley Caves and Paulina Marsh are located in the Fort Rock Basin of central Oregon. The Fort Rock Basin encompasses an area of ~3900 km² that is uniquely situated in an ecotonal setting where the Basin and Range physiographic region meets the High Lava Plains to the north, Cascade foothills to the west, and wooded marsh country of the Klamath Basin to the south. It is a semi-arid high-desert environment with less than 25.4 cm of annual precipitation and landcover dominated by shrub-steppe biotic communities (Franklin and Dyrness 1988; Grayson 1979, 2011; Hampton 1964). Pluvial Fort Rock Lake once inundated the basin during parts of the late Pleistocene, and its recession left four major visible shorelines. Attempts to date the shorelines have proven problematic and the hydrologic history of the basin remains poorly understood (Allison 1979; Forbes 1973; Friedel 1994). Paulina Marsh is the only area of the Fort Rock Basin to regularly hold perennial water today. It provides important habitat and water for plants, animals, and people.

The Fort Rock Basin is situated within the traditional lands of the Northern Paiute, Klamath, and Modoc. Northern Paiute groups once inhabited an area of over 70,000 square miles

that extended from modern day central Oregon down to southern California on the west side, and along the Columbia and Snake Rivers down to central Nevada on the east (Fowler and Liljeblad 1986). Their settlement-subsistence strategies varied by group and region, but usually centered on seasonal economic rounds that involved relocation to different habitats as various resources became available throughout the year (e.g., Couture 1978; Couture et al. 1986; Masten 1985; Steward 1933; Stewart 1939; Whiting 1950). The Modoc and Klamath also occupied areas of the northern Great Basin, though at time of settler contact they were centered on the Lost River Valley and marshes along the eastern base of the Cascades, respectively (Aikens et al. 2011). Both groups followed a two-village settlement system with distinct winter and spring/summer villages. The Modoc and Klamath tended to occupy well-watered areas, but the Modoc relied more heavily on seeds and roots relative to the Klamath whose food economy focused more on fish and other marsh resources (Masten 1985; Sobel 1992; Spier 1930). Northern Paiute, Klamath, and Modoc groups, whose ancestors have inhabited the northern Great Basin for millennia and whose cultural heritage is discussed in this dissertation, continue to live in Oregon today. Their traditional knowledge and ethnographic records demonstrate deep knowledge of the landscape, including the use of innumerable plant species for food, medicine, textiles, tools, construction, and more (e.g., Barrett 1910; Coville 1897; Gatschet 1890; Mahar 1953; Kelly 1932; Park and Fowler 1989; Ray 1963; Sobel and Bettles 2000; Spier 1930; Steward 1933; Train et al. 1941).

Archaeological investigations in the Fort Rock Basin began nearly a century ago with the work of Luther Cressman, whose excavations at Fort Rock Cave in the 1930s uncovered sagebrush sandals and other artifacts beneath Mount Mazama tephra that proved critical to the understanding of human antiquity in North America (Arnold and Libby 1951; Cressman 1942,

1951; Cressman et al. 1940). Cressman's graduate student, Stephen Bedwell, conducted further excavations at Fort Rock Cave and other rockshelters in the basin, which raised the possibility that people entered the region as early as ~15,000 cal BP (Bedwell 1970, 1973). In 1989, the University of Oregon archaeology field school launched the "Fort Rock Basin Prehistory Project" (FRBPP), a ten-year archaeological research program aimed at elucidating paleoenvironment, climate, and settlement-subsistence patterns of the area. The FRBPP was carried out in collaboration with the Lakeview District Bureau of Land Management and resulted in two major volumes (Aikens and Jenkins 1994; Jenkins, Connolly et al., eds. 2004), as well as numerous dissertations, theses, and research papers (e.g., Droz 1997; Friedel 1993; Helzer 2001; Largaespaeda 2001; Moessner 1995; O'Grady 1999; Prouty 1995; Thatcher 2001; Wingard 1998). The project was later geographically expanded and renamed as the "Northern Great Basin Prehistory Project" (NGBPP).

The intended research trajectory of the NGBPP aimed to first examine Late and Middle Holocene settlement-subsistence patterns of the northern Great Basin and nearly all efforts before 2001 were focused as such (Aikens and Jenkins 1994; Jenkins, Connolly et al., eds. 2004). With the last 8000 years of the archaeological record relatively well-understood, the NGBPP field school turned its attention to the earliest evidence of people in the region (Jenkins et al. 2002). Ensuing investigations at Paisley Caves in the Chewaucan Basin led to the discovery of coprolites containing human DNA and other artifacts that collectively constitute some of the earliest evidence of humans in the Americas (Gilbert 2008; Jenkins et al. 2012; Shillito et al. 2020). Paisley Caves research since has been expansive and multi-disciplinary, with a monograph currently in preparation. After Paisley Caves, the field school returned to another site with some of the earliest purported evidence of humans in the region—Connley Caves (Bedwell 1970). I

joined the NGBPP research effort in 2014, and, with Dennis Jenkins, have since led six seasons of excavation at Connley Caves. This dissertation focuses on cultural components of Connley Cave 5 that we excavated between 2014 and 2019.

1.2.1. Connley Caves

Connley Caves is a multicomponent site composed of eight shelters that were eroded by pluvial Lake Fort Rock into the west side of the Connley Hills in the Silver Lake Valley. The caves are situated within a juniper woodland ~45 m above the valley floor (~1356 m above sea level) overlooking Paulina Marsh. Early excavations by Stephen Bedwell in 1967 and 1968 uncovered extensive archaeological components with ~4 m of stratified deposits and produced a radiocarbon age in excess of 13,000 cal BP on charcoal purportedly associated with flaked-stone tools in Cave 4 (Beck et al. 2004; Bedwell 1970, 1973). Connley Caves formed a major foundation of Bedwell's dissertation (Bedwell 1970) and was key to the development of his highly influential Western Pluvial Lakes Tradition hypothesis, which contended that groups who inhabited the western Great Basin ca. 13,000 to 8900 cal BP were highly mobile and focused on lacustrine environments. Ultimately, the expedient nature of the excavations and stratigraphic reversals in radiocarbon ages caused some researchers to question Bedwell's chronology and paleoecological interpretations (Goebel et al. 2011; Goebel and Keene 2014; Grayson 1979; Jenkins et al. 2002).

The University of Oregon field school returned to the site in 2000 with the goal of reassessing the geochronology and paleoecology of the earliest cultural deposits and has since completed eight seasons of excavation (2000, 2001, 2014-2019) (Jenkins et al. 2002, 2017; McDonough and Jenkins 2018; McDonough et al. 2018; Smith et al. 2020). Excavations at the mouth of Connley Cave 5 uncovered well-stratified cultural components reflecting repeated

visits to the site beginning during the terminal Pleistocene and continuing to historic times, with a possible hiatus between ~8000 and 6000 cal BP. The Connley Caves archaeological collection is currently housed at the University of Oregon Museum of Natural and Cultural History, in Eugene, Oregon, where I analyzed the archaeobotanical assemblages from early combustion features, and from whom I borrowed coprolites that I analyzed at the Texas A&M University Palynology Research Laboratory in College Station.

1.2.2. Paulina Marsh

Paulina Marsh is a large wetland (~32 m²) fed by Buck, Bridge, and Silver creeks in the southwest Silver Lake valley, less than 2 km from Connley Caves. As the only recipient of perennial stream flow in the Fort Rock Basin and one of few substantial marshlands in the northern Great Basin more broadly, Paulina Marsh is a prominent environmental feature and provides critical resources for plants, animals, and people. Researchers have hypothesized that the productive marsh habitat was a primary draw for foragers to the Fort Rock Basin (Bedwell 1970; Jenkins et al. 2002; Jenkins, Connolly et al. 2004). As such, understanding its history is vital for interpreting the region's archaeological record. Archaeologists and geomorphologists have conducted surveys within and around Paulina Marsh (Benjamin 1994; Jenkins and Aikens 1994), but sediment cores have never been extracted and studied for the purpose of paleoenvironmental reconstruction. Nearly all of the marsh is privately owned, and I was fortunate that a landowner granted me permission to conduct a sediment coring project on their property.

1.3. Research Structure

Broad questions guiding my dissertation research include: (1) When and why did people visit Connley Caves; (2) where did people forage and what role did plants play in early food

economies; (3) do subsistence data at Connley Caves reflect foraging behavior that is consistent with prevailing settlement-subsistence models; and (4) how did changing climate conditions affect plant communities, and how did people respond? I carried out three stand-alone projects to address each of these research questions.

Chapter II examines foraging behavior and the role of plants in the food economy of Paleoindian groups through paleoethnobotanical analysis of five combustion features from stratified deposits dating to the terminal Pleistocene and Early Holocene in Connley Cave 5. Additionally, I present archaeobotanical data from a column sample to serve as a control and introduce 17 new radiocarbon ages to develop a chronological framework for the features. Because botanical remains become incorporated into archaeological sites through both natural and anthropogenic processes, I develop a set of criteria for evaluating the likelihood of dietary association that considers the taphonomy, spatial distribution, ecology, and ethnographic uses of each taxon. These data reveal new aspects of seasonality and foraging choices at the site-level and contribute new taxa to the known Paleoindian plant food economy. I then consider these data within the broader dietary record from late Pleistocene sites in North America to investigate emerging patterns of plant use and subsistence strategies on a continental scale.

Chapter III presents multiproxy dietary data and new radiocarbon ages from coprolites found in a possible latrine or midden area in Connley Cave 5 to investigate foraging behavior, human health, and seasonal site use during the Bergen Period. My analyses of palynological, macrobotanical, parasitological, and faunal constituents result in fine-grained snapshots of individual dietary decisions and meal compositions that are rarely obtained in the archaeological record. I use evaluative criteria to assess whether the coprolites are of human origin and conduct

exploratory statistics to examine diachronic trends and patterns of co-occurrence among primary taxa. Finally, I ask whether patterns of foraging behavior interpreted from the coprolites and archaeological data fit within the prevailing settlement-subsistence models proposed for the Bergen Period.

Chapter IV presents new chronological, geomorphological, and palynological data from five sediment cores that I extracted from Paulina Marsh in 2018 and 2019. I use multiple lines of evidence including pollen, particle size, and elemental data, from a 2.47 m core from the Buck Creek floodplain in the southwest marsh to examine vegetation change and site depositional history during the Early and Late Holocene. These data constitute the first Early Holocene pollen record from the Fort Rock Basin and reveal a fluctuating Late Holocene record that is consistent with human paleoecological models proposed to explain changing settlement-subsistence patterns during the last 3000 years in the Fort Rock Basin (Jenkins 1994; Jenkins, Connolly et al. 2004). These patterns compare well with other paleoclimate proxy records in the northern Great Basin and provide insights on the effects of globally recognized climatic events on vegetation communities in the Fort Rock Basin.

Chapter V summarizes the major findings and implications of this dissertation and offers ideas for potential pathways of future research. In addition to refining the archaeological record of the northern Great Basin, the research presented here has broader implications for foraging behavior and human adaptations in desert environments around the world and contributes to the fields of North American biogeography and paleoecology.

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CHAPTER II
EXPANDING PALEOINDIAN DIET BREADTH:
PALEOETHNOBOTANY OF CONNLEY CAVE 5, OREGON, USA

Katelyn N. McDonough, Jaime L. Kennedy, Richard L. Rosencrance, Justin A. Holcomb,
Dennis L. Jenkins, and Kathryn Puseman

Current models of human settlement-subsistence during the late Pleistocene (ca. 11,700 calendar years ago [cal BP] and older) in North America are predominantly derived from and biased toward faunal data. Although Paleoindian food economies undoubtedly included plants, the paucity of archaeobotanical assemblages from well-dated contexts limits our view of dietary diversity and foraging choices. Recent studies have successfully recovered fragile dietary remains from Pleistocene-aged contexts and reinforce the need for a paleoethnobotanical perspective for understanding variability in Paleoindian lifeways (Blong et al. 2020; Dent 2007; Dillehay et al. 2008; Duke et al. 2018; Gingerich 2011; Gingerich and Kitchel 2015; Hollenbach 2007; Kennedy 2018; Rhode and Louderback 2007; Roosevelt et al. 1996; Taylor et al. 2019). This paper presents a new botanical dataset from Connley Caves (35LK50), Oregon, which contributes to a growing body of paleoethnobotanical research showing that plants were important components of Paleoindian subsistence.

Understanding Pleistocene subsistence strategies is critical to models of mobility and questions regarding how humans settled North America. Historically, early models of Paleoindian land use centered on evidence from early archaeological sites in the Great Plains and American Southwest (Haynes 1966; Heizer and Baumhoff 1970; Martin 1973), where extinct

megafaunal remains including mammoth (*Mammuthus columbi*) and bison (*Bison antiquus*) were associated with fluted-point technology (Figgins 1933; Sellards 1938, 1952). Researchers posited a Paleoindian adaptive strategy focusing on specialized big-game hunting and high mobility (Kelly and Todd 1988; Surovell and Waguespack 2009; Waguespack and Surovell 2003), with some interpreting that early Paleoindians targeted megafauna to the point of their extinctions (Martin 1973, 1984, 2005; Martin and Steadman 1999). Other researchers have challenged the view of Paleoindians as specialized big-game hunters (Cannon and Meltzer 2004; Erlandson et al. 2007, 2015; Hemmings 2004; Hockett 2007; Hockett et al. 2017; Madsen 2007; Pinson 2007), and rigorous debate continues regarding the importance of large mammals in early Paleoindian subsistence (Byers and Ugan 2005; Cannon and Meltzer 2008; Fiedel and Haynes 2004; Grayson and Meltzer 2003; Haynes and Hutson 2013; Kornfeld 2007; Meltzer 2020; Stewart et al. 2021; Waguespack 2013).

Recent excavations at the Paisley Caves and Cooper's Ferry sites suggest that people in the Great Basin and Columbia Plateau employed Western Stemmed Tradition (WST) hunting technology coeval with the Clovis Tradition east of the Rocky Mountains and south of the Colorado River (Davis et al. 2019; Jenkins et al. 2012; Shillito et al. 2020). Other sites show a continuation of WST forms (Haskett and Lind Coulee) contemporaneous with Younger Dryas-aged fluted-point complexes from the North American Great Plains and Northeast (Rosencrance 2019; Smith et al. 2020). Despite this growing Paleoindian record within the Intermountain West, researchers have yet to uncover unequivocal evidence of the hunting of extinct megafauna (Goebel et al. 2011; Grayson 2016). Current models predict that groups using WST technology hunted artiodactyls but overall employed more diverse subsistence strategies relative to groups on the Great Plains (Elston et al. 2014; Hockett 2007; Madsen 2015), but the degree of resource

diversity and its relationship to settlement patterns continues to be debated (Duke and Young 2007; Jones et al. 2003; Smith and Barker 2017). Like elsewhere in North America, however, contemporary Great Basin models rely chiefly on faunal datasets and related caloric contents (e.g., Elston and Zeanah 2002; Elston et al. 2014).

The role of plants in early Paleoindian lifeways throughout the Americas has received significantly less attention. The skew in archaeological discourse toward hunting over gathering is at least partially due to the dearth of Pleistocene-aged archaeobotanical assemblages, especially in temperate North America. As shown in Figure 2.1, among late Pleistocene sites with preserved subsistence material in North America, less than 10% have yielded substantial ($n > 5$ botanical specimens) and unequivocal dietary plant remains. Botanical remains are clearly underrepresented in the archaeological record, but evidence is mounting that some early Paleoindian groups foraged for diverse plant species by at least the Younger Dryas (ca. 12,900-11,700 cal BP) (Blong et al. 2020; Dent 2007; Dillehay et al. 2008; Gingerich 2011; Hollenbach 2007; Kennedy 2018; Rhode and Louderback 2007; Roosevelt et al. 1996; Sandweiss 2003; Taylor et al. 2019; see also Dillehay et al. 2012; Ranere and López 2007). Here we focus on temperate North America, but a review including all regions of North, Central, and South America is still needed to provide a Pan-American perspective on Paleoindian plant use. Within temperate North America, some regional trends are apparent in the existing data, including a prevalence of berries and nut mast east of the Rocky Mountains versus a broad range of seeds, fruits, tubers, cactus, and leafy greens in the Great Basin. The latter is potentially unexpected, given previous models of rapid expansion and focus on high-ranked resources but is less surprising when regional and seasonal availability of food resources are considered.

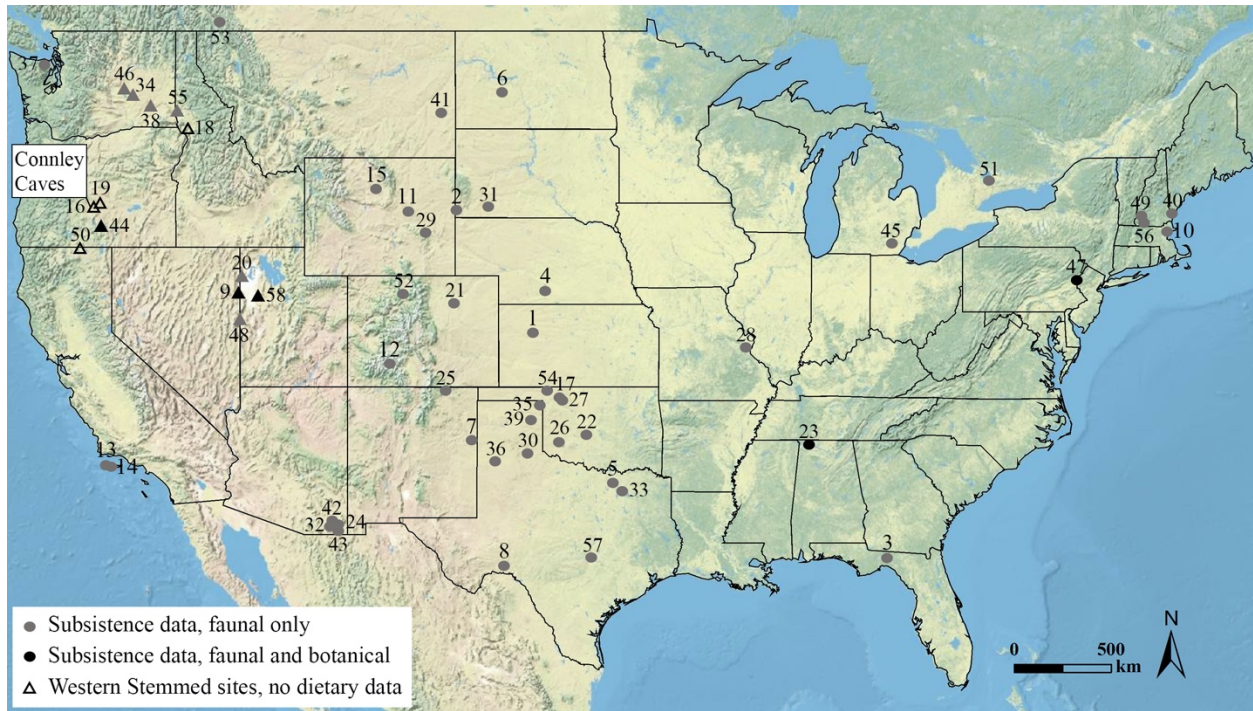


Figure 2.1. Map displaying location of Connley Caves and Paleoindian sites with subsistence data older than 11,700 cal BP (subsistence associations are from Anderson et al. 2015; Gingerich and Kitchel 2015; Grayson and Meltzer 2015; Haynes and Hutson 2013; Hill 2008; Hurst et al. 2010; Kilby et al. 2021; Lothrop et al. 2016; Mackie et al. 2020, botanical data with total MNI of less than five seeds were considered unreliable and excluded from the map). Sites with Western Stemmed technology are displayed as triangles and sites with other tool technologies are displayed as circles. 1: 12 Mile Creek; 2: Agate Basin; 3: Alexon; 4: Allen; 5: Aubrey; 6: Big Black; 7: Blackwater Draw; 8: Bonfire Shelter; 9: Bonneville Estates Rockshelter; 10: Bull Brook; 11: Casper; 12: Cattle Guard; 13: Channel Islands SMI-261; 14: Channel Islands SRI-512; 15: Colby; 16: Connley Caves; 17: Cooper; 18: Cooper’s Ferry; 19: Cougar Mountain Cave; 20: Danger Cave; 21: Dent; 22: Domebo; 23: Dust Cave; 24: Escapule; 25: Folsom; 26: Howard Gully; 27: Jake Bluff; 28: Kimmswick; 29: La Prele; 30: Lake Theo-Folsom; 31: Lange-Ferguson; 32: Lehner; 33: Lewisville; 34: Lind Coulee; 35: Lipscomb; 36: Lubbock Lake; 37: Manis; 38: Marmes Rockshelter; 39: Miami; 40: Michaud; 41: Mill Iron; 42: Murray Springs; 43: Naco; 44: Paisley Caves; 45: Pleasant Lake; 46: Sentinel Gap; 47: Shawnee Minisink; 48: Smith Creek Cave; 49: Tenant Swamp; 50: Tule Rockshelter; 51: Udora; 52: Upper Twin Mountain; 53: Wally’s Beach; 54: Waugh; 55: Wewukiyepuh; 56: Whipple; 57: Wilson Leonard; 58: Wishbone.

1.5. Pleistocene Subsistence in Temperate North America

Archaeological dietary records from late Pleistocene contexts in temperate North America increasingly suggest that by at least the Younger Dryas, Paleoindian groups had

developed regionally adapted subsistence strategies that included plant resources. To our knowledge, however, only five sites across this large area have produced dietary plant remains consisting of five or more constituents from cultural contexts securely dated to before 11,700 cal BP. These include Shawnee Minisink, Dust Cave, Paisley Caves, Bonneville Estates Rockshelter, and Wishbone. Archaeobotanical assemblages are known from additional sites, but these should be treated with caution due to their small sample size or equivocal context. We review these records here to provide a continental perspective on plant use in the late Pleistocene and earliest Holocene. We find two important patterns: (1) few plant remains have been recovered from sites predating 11,700 cal BP; and (2) plants are more common at Paleoindian sites postdating 11,700 cal BP and are present in every region by ~10,000 cal BP.

In the Northeast, the largest and most frequently cited archaeobotanical assemblage comes from the Clovis site of Shawnee Minisink (Pennsylvania), dated to a mean age of $10,937 \pm 15$ ^{14}C BP (Dent and Kauffman 1985; Gingerich 2011, 2013). Of the carbonized plant remains recovered from the 1970s excavations, Dent (2007) interpreted hackberry (*Celtis* sp.; $n = 1$), blackberry (*Rubus* sp.; $n = 15$), hawthorn plum (*Crataegus* sp.; $n = 15$), and grape (*Vitis* sp.; $n = 3$) as dietary. More recently excavated hearths contained abundant charred hawthorn seeds ($n = \sim 132$) and lesser amounts of charred hickory nut (*Carya* sp.) ($n = 5$) (Gingerich 2011, 2013). Gingerich (2011) argues that at Shawnee Minisink, hawthorn fruit and possibly hickory nut represent the only edible taxa found within the hearth features, and thus provide the sole evidence of Paleoindian plant consumption at the site. Gingerich attributes the remains to opportunistic foraging near camp, rather than focused plant procurement, noting their low-processing cost and compatibility with hunting-focused, high-mobility lifeways. Smaller and less contextually secure archaeobotanical assemblages have been recovered from several other sites

in the Northeast with various post-Clovis fluted-point complexes. A directly dated hearth at Michaud (Maine) ($10,200 \pm 200$ ^{14}C BP) yielded a fragment of a charred berry seed (Spiess et al. 1998), and a 20-cm level at Hedden (Maine) (dated by dispersed charcoal to $10,500 \pm 60$ and $10,580 \pm 60$ ^{14}C BP) produced 11 charred fruit seeds, but the latter's association with cultural features is unclear (Asch Sidell 1999; Gingerich and Kitchel 2015). Flotation of hearth fill at Colebrook (New Hampshire) (dated to $10,290 \pm 170$ ^{14}C BP and $10,220 \pm 50$ ^{14}C BP) yielded four charred seeds that have yet to be positively identified (Boisvert and Kitchel 2018; Kitchel and Boisvert 2011), and a small, undated pit feature associated with Vail/Debert projectile points at Jefferson III (New Hampshire) yielded one charred water lily seed (*Nymphaea odorata*) (Boisvert 2012; McWeeney 2007). The current record of Pleistocene plant food in the Northeast is limited but suggests primary use of berries and nuts.

In the Southeast, the primary Pleistocene archaeobotanical data come from Dust Cave (Alabama). Researchers have interpreted the Younger Dryas occupation in Zones U and T (ca. 12,500-11,200 cal BP; Thulman 2017) as an autumn/early winter campsite where inhabitants wielding Quad/Beaver Lake and Dalton projectile-point technology consumed a variety of charred nuts (hickory, black walnut [*Juglans nigra*], acorn [*Quercus* sp.], hazelnut [*Corylus* sp.]), berries (blackberry and grape), and possibly seeds (*Chenopodium* sp.) (Driskell 1996; Hollenbach 2007; Hollenbach and Walker 2010). The carbonized archaeobotanical assemblage from four hearth features is dominated by nut mast, with hickory being most common (Hollenbach 2007). Hollenbach (2007:146) contends that these remains, especially the hickory nuts, reflect deliberate foraging that would have affected the schedule and mobility of Paleoindian groups. The dietary nature of other late Pleistocene archaeobotanical assemblages in the Southeast is less clear, as they consist of fragments of charred hickory nuts from non-feature

contexts within the Clovis component at Cactus Hill (Virginia) (component dated to $10,920 \pm 250$ ^{14}C BP) and a single nut fragment from uncertain and undated contexts at Austin Cave (Tennessee) (Gingerich and Kitchel 2015; Haynes and Hutson 2013; McAvoy and McAvoy 1997). The prevalence of hickory nut in the Pleistocene record, as well as in later sites of the Early Holocene (e.g., Rollins Bluff Shelter and LaGrange Bluff Shelter, Alabama) demonstrates the importance of this plant food resource in temperate eastern North America (Hollenbach 2005, 2007).

Archaeobotanical assemblages from the Great Plains and Rocky Mountains are small and mostly limited to hackberry. The largest assemblage from the region consists of ~10 charred hackberry seeds from the Lewisville site (Texas) (Crook and Harris 1958; Haynes and Hutson 2013); however, those materials were excavated in the 1950s and lack clear association with any cultural material (see discussion by Surovell and Waguespack 2009:87). Other Texas sites with hackberry include Lubbock Lake ($n = 5$) and Gault ($n = 4$), but the association of those plant remains with cultural features and whether they are all charred is unclear (Haynes and Hutson 2013; Hemmings 2004; Johnson 1987). At Big Eddy (Missouri), Lopinot and colleagues (1998) recovered two charred chenopod fragments from a discrete pile of knapping debris (Feature 41 is undated but roughly 10 cm higher in elevation than charcoal dated to $10,470 \pm 80$ ^{14}C BP), and charred grape pips and a nutshell fragment were found in a sediment column, possibly as a result of natural accumulation. Overall, compelling dietary plant remains are generally lacking from sites in the Great Plains and Rocky Mountains until the Holocene. In their recent publication of archaeobotanical remains from Bull Creek (Oklahoma), Bement and colleagues (2020) discuss how the charred seeds of the amaranth (Amaranthaceae), sedge (Cyperaceae), and possibly nightshade (Solanaceae) families recovered from a hearth dated to 10,270 cal BP fit with the

general trend of increased presence and diversity of plant foods east of the Rocky Mountains following the Holocene onset (e.g., Thoms 2008).

The earliest sites from the American Southwest and Pacific Coast similarly lack dietary plant remains. Pleistocene sites with subsistence evidence in the Southwest, such as those in the San Pedro Valley, are limited to faunal data (Haury et al. 1953; Haynes and Huckell 2007; Haynes and Hutson 2013). Despite people inhabiting the Pacific Coast of North America for at least ~13,000 years (Erlandson et al. 2011; Johnson et al. 2002), clear evidence of plant consumption is lacking until the earliest Holocene. The Channel Islands were occupied throughout the Younger Dryas, but definitive dietary plant remains have yet to be recovered from Pleistocene contexts. Instead, researchers have recovered charred geophyte (*Brodiaea*-type corm and *Calochortus* bulb), nutshell (likely *Pinus muricata* D. Don), berry pit (*Arctostaphylos* spp.) and a seed (*Camissonia*) from an ~11,500 cal BP cluster of artifacts and burned rock at CA-SRI-997/H (Erlandson et al. 2019, 2020; Gill et al. 2021) and a geophyte-based plant food economy was in place on the islands by ~10,000 cal BP (Gill 2015; Gill and Hoppa 2016). Similarly, nuts and small seeds appear in the archaeological record of mainland California after 10,700 cal BP (Rosenthal and Fitzgerald 2012).

In the Great Basin, relatively robust dietary plant assemblages are known from multiple sites in contexts clearly dating to the late Pleistocene: Paisley Caves (Oregon) (Blong 2020; Kennedy 2018; Taylor et al. 2019), Bonneville Estates Rockshelter (Nevada) (Rhode and Louderback 2007), and Wishbone (Utah) (Duke et al. 2018; Smith et al. 2020). The botanical contents of five Younger Dryas-aged hearths at Paisley Caves suggest that humans consumed small seeds from grasses (Poaceae), chenopods and amaranths (Amaranthaceae), mustards (Brassicaceae), and borages (Boraginaceae), as well as parenchymous tissue of geophytes

during the summer and fall seasons (Kennedy 2018). Coprolites elsewhere at the site directly dated to before 11,700 cal BP contained seeds of the amaranth family, rose fruit (Rosaceae), high frequencies of legume family (Fabaceae) pollen, and common occurrences of phytoliths indicating regular consumption of leafy greens (Blong et al. 2020). Finally, Jenkins and colleagues (2013) recovered carrot family (Apiaceae-type) starch as well as grass-seed starch and phytoliths from a polished and battered handstone that dates to around ~13,600 cal BP.

At Bonneville Estates Rockshelter, paleoethnobotanical analysis of eleven hearths spanning from ~13,000 to 11,700 cal BP found charred cactus (*Opuntia* sp.) parts and a variety of small seeds including grasses (*Leymus* sp., *Eriocoma hymenoides*, and *Sporobolus* sp.), goosefoot (*Chenopodium* sp.), sunflower (Asteraceae), bulrush (*Scirpus* sp.), and mustard (Brassicaceae), all interpreted as economic (Rhode and Louderback 2007). At Wishbone, the charred botanical contents of a hearth dating to ~12,300 cal BP suggest economic use of red maid (*Calandrinia* sp.), pitseed goosefoot (*Chenopodium berlandieri*), and tobacco (*Nicotiana* sp.) (Duke et al. 2018; Smith et al. 2020). All three sites contain sophisticated, but flexible, Haskett projectile-point technology (Duke 2015; Pratt et al. 2020; Rosencrance 2019), suggesting that Haskett makers had diverse diets that included small seeds, roots, fruits, cacti, and leafy greens. Danger Cave (Utah) is another site in the Bonneville Basin where researchers recovered charred seeds and fruits from > 11,500 cal BP deposits; however, dietary association of those materials is inconclusive (Rhode and Louderback 2007).

As this review demonstrates, current evidence for Paleoindian plant consumption from throughout temperate North America is remarkably scarce. No doubt this is due to a number of factors such as preservation, sampling, and the actual importance of such resources in people's diets. The most reliable early evidence in eastern North America comes from Shawnee

Minisink and Dust Cave, where archaeobotanical assemblages are of sufficient size and context to confidently interpret dietary use. While those sites provide a limited view of plant use—being over a thousand kilometers and centuries of occupation apart—they indicate late Pleistocene foragers primarily procured nuts and fruits. Sites in the Great Plains generally support this pattern as well, although Pleistocene evidence is equivocal in terms of human use, and it is not until the Early Holocene that clear evidence of plant consumption appears. In the Southwest and California clear evidence of plant foods is also absent prior to the Early Holocene. Archaeobotanical assemblages from the Great Basin, finally, suggest that WST groups incorporated diverse plants into their diet by at least the beginning of the Younger Dryas, and likely sooner. More data are needed across North America to test whether incorporation of plants was gradual, with Paleoindians in some regions expanding diets earlier than in other, or if our current interpretations are hampered by poor sampling.

Recent research at Connley Caves, a multicomponent WST site located in central Oregon, offers an opportunity to gain a diachronic view of plant use. Multiple stratified cultural components with an extraordinary volume and diversity of tools suggest that some periods of site use were more than brief stopovers, presenting potential for a broader view of subsistence than typically represented at logistical stopovers (Bedwell 1970; Donham et al. 2020; Jenkins et al. 2017; McDonough and Jenkins 2018; McDonough et al. 2018). Additionally, the site's location at the intersection of two physiographic regions and its position between the valley floor and uplands allows ready access to a variety of plant communities—providing a rare look at foraging behavior in an ecotonal setting (McDonough 2019; Prouty 1994) (Figure 2.2).

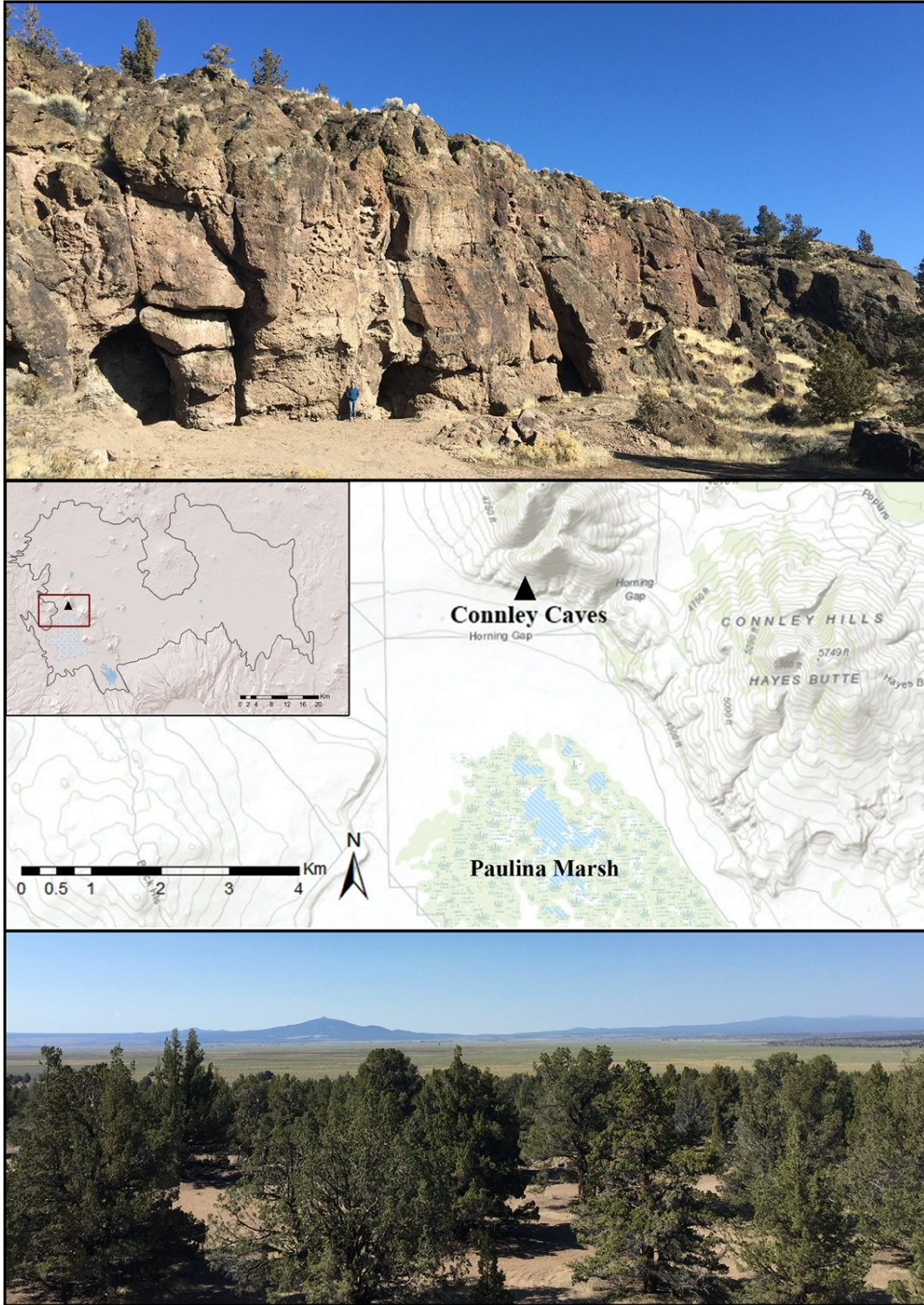


Figure 2.2. Top panel: view of the Connley Caves looking north-northeast. See person in blue standing at eastern edge of Cave 5 excavation block for scale. Middle panel: location of the site within the Fort Rock Basin showing proximity to Paulina Marsh. Bottom panel: view looking south from the top of the Connley Caves toward Paulina Marsh with Hager Mountain in the distance.

Here we present archaeobotanical data and 17 new radiocarbon ages from five combustion features spanning the Pleistocene-Holocene transition in Connley Cave 5 (PHT; ca. 13,000 to 8,200 cal BP). Analyses of the cultural components above and below those discussed here are ongoing and will be reported in future publications. Our objectives in this paper are to: (1) characterize plant use and foraging activities at Connley Caves during the PHT; (2) consider how these data fit into the traditional site narrative and the growing body of archaeobotanical data for the Pleistocene Paleoindian period more broadly; and (3) discuss implications for current settlement-subsistence models based on caloric optimization.

1.6. Connley Caves Site Background and Environmental Setting

Connley Caves first gained recognition following Stephen Bedwell's excavations in the 1960s that uncovered artifacts in purported association with charcoal dating to ~13,000 cal BP (Beck et al. 2004; Bedwell 1970, 1973). The site also played an important role in the development of Bedwell's (1970, 1973) Western Pluvial Lakes Tradition concept, which popularized the idea that WST groups in the Great Basin were "tethered" to lacustrine settings during the late Pleistocene. For over 50 years, scholars have speculated about the cultural chronology of Connley Caves (Bryan 1980; Grayson 1979; Jenkins et al. 2002), with some archaeologists questioning whether the site was heavily used prior to the Early Holocene (Goebel et al. 2011:493). The University of Oregon Archaeology Field School returned to the site between 2000-2001 and 2014-2019 with the goal of refining the chronological, ecological, and technological records (Jenkins et al. 2002, 2017; McDonough and Jenkins 2018; McDonough et al. 2018). Our recent excavations in Connley Caves 4 and 5 uncovered multiple cultural components that span the Younger Dryas (ca. 12,900 to 11,700 cal BP; Rasmussen et al. 2014) through Early Holocene (ca. 11,600 to 8200 cal BP; Walker et al. 2012, 2019). Here we provide

the first look at the Paleoindian components recently excavated in Connley Cave 5, which contain extensive WST lithic and osseous tool assemblages, discrete activity areas, and cultural features (McDonough and Jenkins 2018; McDonough et al. 2018).

1.6.1. Physiographic and Environmental Setting

Connley Caves are located on the traditional lands of the Klamath, Modoc, and Yahooskin in the Fort Rock Basin of central Oregon. The Fort Rock Basin is the northwestern-most drainage system in the Great Basin and encompasses an area of ~3900 km² bordered by the High Lava Plains to the north, Cascade foothills to the west, and woodland marshes of the Klamath Basin to the south. It is a semi-arid high desert with less than 25.4 cm of annual precipitation (Grayson 1979, 2011; Hampton 1964). Ridgelines divide the Fort Rock Basin into three valleys: Silver Lake, Christmas, and Fort Rock. Connley Caves comprise at least eight rockshelters situated in the south-facing slope of the Connley Hills overlooking Paulina Marsh in the Silver Lake Valley (see Figure 2.2). The rockshelters are eroded into a steep escarpment of welded tuff and breccia with incorporated nodules of toolstone-quality fine-grained volcanic (FGV) rock (Donham et al. 2020).

Several habitats are accessible from Connley Caves due to their position in the ecotone between the Basin and Range and the High Lava Plains provinces (Aikens and Jenkins 1994; Bureau of Land Management 2000; Prouty 1994). The caves sit around 45 m above the valley floor (~1356 m above sea level [ASL]) within a woodland belt of western juniper (*Juniperus occidentalis*) and a sparse understory dominated by sagebrush (*Artemisia*), rabbitbrush (*Chrysothamnus*), and grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and western needlegrass (*Achnatherum occidentale*) (Bureau of Land Management 2000; Franklin and Dyrness 1988). Absence of juniper macrofossils below

the Mazama tephra (ca. 7650 cal BP) in the rockshelter deposits suggests that these trees did not grow on site during the late Pleistocene or Early Holocene. Juniper woodland fades into a tall sagebrush (*Artemisia tridentata*) steppe community at the base of the Connley Hills followed by dune formations and alkaline playa that support salt desert shrub communities of greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), and budsage (*Artemisia spinescens*) along the northern margins of Paulina Marsh (Bureau of Land Management 2000; Franklin and Dyrness 1988). Emergent herbs and grass-like plants such as rushes (e.g., *Cyperus*, *Scirpus*, *Schoenoplectus*), sedges (*Carex*), and cattail are common throughout the marsh. As the only recipient of perennial streamflow in the Fort Rock Basin, Paulina Marsh's mosaic of wetland patches and meadows is a critical source of water for flora and fauna.

The Great Basin landscape transformed during the PHT as deep lakes receded, biotic communities shifted, and some animal species became extinct (Goebel et al. 2011; Grayson 2011, 2016). Grayson (1979) interprets the Connley Caves faunal assemblage from below the Mazama tephra as indicative of cooler temperatures, greater effective moisture, and higher percentages of herbaceous vegetation, based on the presence of pika (*Ochotona princeps*), which cannot withstand temperatures above ~85° F (MacArthur and Wang 1973; Smith 1974). This corresponds well with regional pollen records that generally reflect more mesic- and cool-adapted plant communities during the late Pleistocene relative to the Early Holocene (Beck et al. 2018; Mehringer 1985; Minckley et al. 2004, 2007; Wigand 1989; Wigand and Rhode 2002).

1.7. Materials and Methods

This study examines sediment samples collected between 2017 and 2019 in Connley Cave 5, including eleven samples from inside five combustion features, two sediment samples from outside of the features, and 17 samples from an associated sediment column (Figure 2.3).

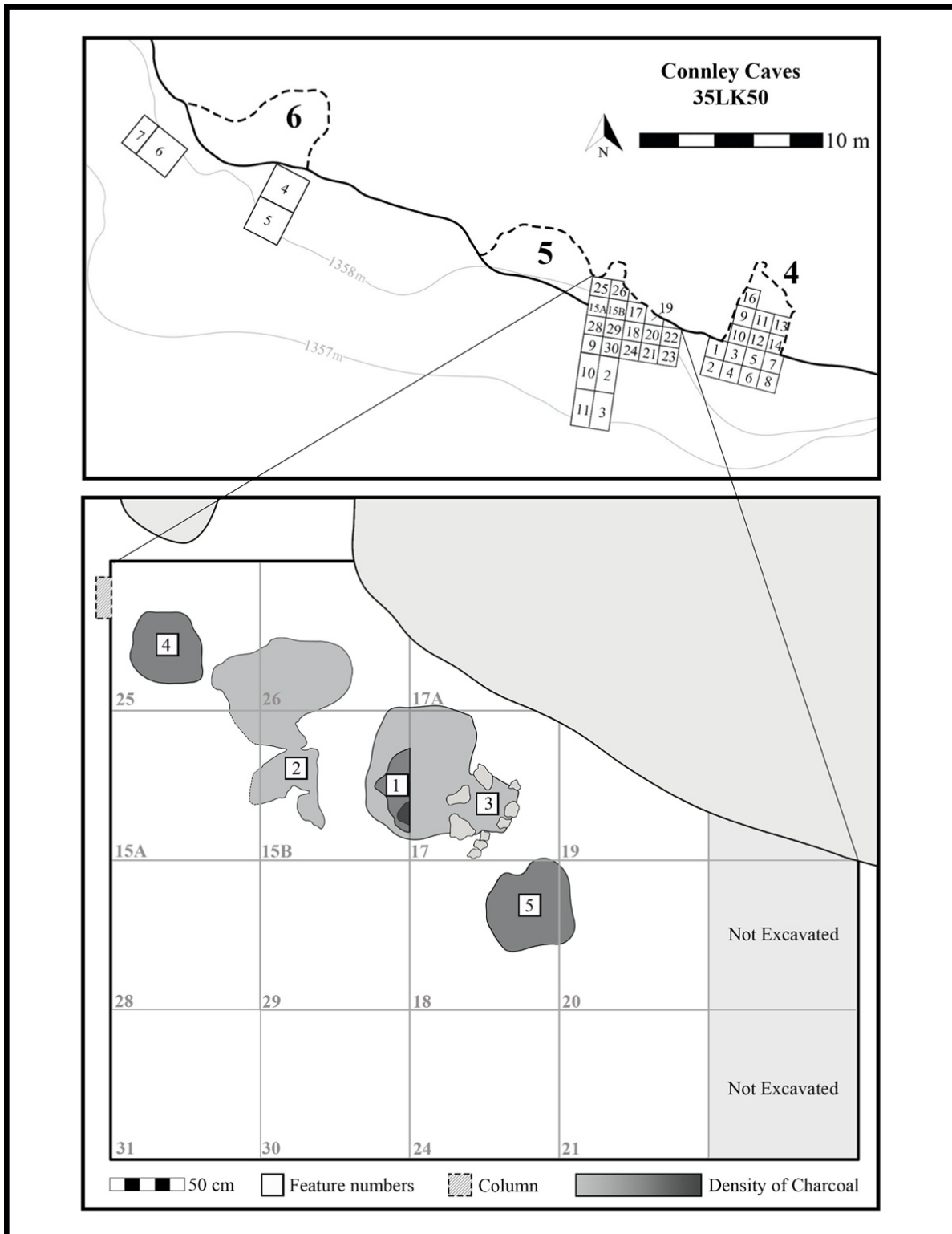


Figure 2.3. Planview of Connley Cave 5 (2014 to 2019) block showing excavation grid and the locations of features and column sample discussed in the text. Note that the bottom image only reflects horizontal relationships and does not account for the vertical separation between features.

We excavated features in 5-cm, within-strata increments, resulting in multiple bulk sediment samples per feature. We analyzed at least two 1-liter subsamples from different areas within each feature to obtain a representative sample and used a 5-cm vertical sampling technique to collect a 142-cm thick sediment column from the west wall of Unit 25. Sample increments were sometimes smaller due to stratigraphic transitions within the arbitrary 5-cm increments or larger due to small collapses of loose sediment matrix.

1.7.1. Feature Descriptions

Combustion features represent unique archaeological contexts that have the ability to inform about human behavior at the individual scale, reflecting a single event or repeated use over weeks, months, or years. Such features can take many forms in archaeological sites, and we follow the definitions outlined by Mentzer (2014). Here “combustion feature” is used to broadly characterize areas where evidence of fire is interpreted as resulting from cultural activity. The term “hearth” is reserved for instances in which all or most of the original structure of a domestic fire is preserved. Hearths that are still recognizable as the remnants of a domestic fire, but are less intact, are referred to as “hearth areas.” Features that may represent obscured hearths, multiple hearths, and/or rake-outs are designated as “combustion areas.” Combustion features, and hearths in particular, are useful for delineating ancient living surfaces and identifying activity areas; however, it is important to consider the type of feature and the specific anthropogenic event(s) it may represent (Black and Thoms 2014; Goldberg and Sherwood 2006; Goldberg et al. 2012; Mentzer 2014). Discrete and expedient hearths are more likely to represent single events and may therefore provide a narrower view of human behavior. Reworked hearths, combustion features, and combustion areas may represent multiple events that reflect a broader view of behavior.

During excavation, we assigned feature numbers using a three-part system beginning with the unit number, followed by feature type, and the order in which features were encountered in that unit (for example, 15B-HF-2 was the second hearth feature excavated in Unit 15B). For clarity, features discussed here are referred to from oldest to youngest with the alternative designations of Features 1 through 5. We describe these features below. Additional details and images of all features can be found in Appendix A (Figures A.1 and A.2; Table A.1).

1.7.2. Radiocarbon Dating

To establish chronological control, we submitted piece-plotted charcoal from within each combustion feature for radiocarbon dating. Prior to submission, we identified the dated charcoal samples to the lowest possible taxonomic level to distinguish short-lived species and avoid the old-wood effect, which may result in erroneously old ages. We conducted chemical pretreatment (acid-base-acid) and combustion of six samples at the University of Nevada, Reno (UNR) Human Paleoecology Laboratory and subsequently submitted each sample to the Pennsylvania State University AMS Radiocarbon Laboratory for graphitization and measurement. The remaining 11 samples were pretreated, combusted, graphitized, and measured by either Penn State or Direct AMS (Table 2.1).

Table 2.1. Radiocarbon ages on *Artemisia* charcoal from cultural features in Connley Cave 5.

Feature Number	Feature Type	Catalog Number	Lab Number	Radiocarbon Date	95.4% Probability	LU ^b
5	Hearth	5/18-53-7 ^a	PSUAMS#5246	9050 ± 30	10,250-10,180	5
5	Hearth	5/18-53-10	D-AMS 24523	9170 ± 40	10,490-10,230	5
5	Hearth	5/18-53-12 ^{a,c}	PSUAMS#5247	9500 ± 30	11,070-10,590	5
4	Hearth	5/25-15-35 ^a	PSUAMS#5007	9985 ± 35	11,690-11,260	4b
4	Hearth	5/25-16-4	D-AMS 30300	10,010 ± 50	11,740-11,270	4b
4	Hearth	5/25-15-41 ^c	PSUAMS#6711	10,165 ± 35	11,940-11,640	4b
4	Hearth	5/25-16-64 ^{a,c}	PSUAMS#5006	10,210 ± 40	12,010-11,740	4b
3	Hearth Area	5/17-51-95	D-AMS 30299	10,115 ± 50	11,940-11,400	4b
3	Hearth Area	5/17-51-96 ^a	PSUAMS#5008	10,120 ± 35	11,930-11,400	4b
3	Hearth Area	5/17-50-12 ^a	PSUAMS#5009	10,190 ± 35	11,970-11,730	4b
2	Combustion Area	5/15B-31-50	D-AMS 30298	10,030 ± 95	11,880-11,240	4b
2	Combustion Area	5/15B-32-25	PSUAMS#7103	10,150 ± 40	11,940-11,500	4b
2	Combustion Area	5/15B-32-38	PSUAMS#6712	10,275 ± 35	12,440-11,820	4b
2	Combustion Area	5/15B-32-21	PSUAMS#7104	10,290 ± 35	12,450-11,830	4b
1	Hearth	5/15B-36-50	PSUAMS#6715	10,420 ± 35	12,600-12,090	4a
1	Hearth	5/15B-36-49	PSUAMS#6714	10,490 ± 35	12,630-12,190	4a
1	Hearth	5/15B-36-51	PSUAMS#6716	10,560 ± 35	12,690-12,480	4a

1.7.3. Archaeobotanical Analysis

We processed, sorted, and analyzed the bulk sediment samples at the Great Basin Research Lab, University of Oregon Museum of Natural and Cultural History. Though water flotation is the preferred method in open-air sites where botanical material is only preserved through carbonization (Gasser and Adams 1981; Minnis 1981; Pearsall 2016), flotation is riskier

in dry cave environments due to the destructive effects of wet-dry cycles on desiccated plant remains (Bryant 1989; Chiou et al. 2013; Hageman and Goldstein 2009; Thomas 1985). Our study used dry-sieving protocol adopted from Kennedy's analysis of rockshelter deposits at Paisley Caves, involving size fractioning of each dry sample through a set of geological sieves (4 mm, 2 mm, 1 mm, and 0.25 mm) (Kennedy 2018:138-139). We sorted botanical remains using a Richter Optica S2D-SPS Digital 10x/30x Stereo Microscope with ToupCam attachment (Pearsall 2016:104-105). From the 4-mm and 2-mm size fractions, we sorted and quantified all carbonized plant material, bone, eggshell, and debitage. Fish vertebrae were easily diagnosed, and we counted these elements separately from other faunal remains. From the 1-mm fraction, we collected all carbonized non-wood plant taxa (e.g., seeds, fruits, nuts), debitage, and fish vertebrae. From the 0.25-mm size fraction we collected all carbonized non-wood plant taxa and fish vertebrae.

Following protocols outlined above for charcoal, we identified each non-wood macrobotanical specimen to the lowest possible taxonomic level using comparative seed collections housed at the University of Oregon Museum of Natural and Cultural History and Texas A&M University, online databases (United States Department of Agriculture [USDA] PLANTS 2017), and identification manuals (Bonner and Karrfalt 2008; Cappers and Bekker 2013; Delorit 1970; Martin and Barkley 1961). Our nomenclature follows Hitchcock and Cronquist (2018), and we referenced identified plant taxa with ecological data (USDA 2014, 2017) and ethnographic accounts of plant use by Indigenous groups of the Great Basin and California (Chamberlin 1911; Coville 1897; Fowler 1986, 1992; Kelly 1932; Liljebblad and Fowler 1986; Mahar 1953; Park and Fowler 1989; Ray 1963; Rhode 2002; Stewart 1939; Train et al. 1941; Zigmond 1981).

Plant materials become incorporated, modified, and preserved within archaeological sites through a variety of natural and anthropogenic processes (Gallagher 2014; Minnis 1981; Pearsall 2016:34–44). To understand how the botanical assemblage at Connley Caves was formed and to assess potential biases in our samples, we considered anthropogenic and ecological factors contributing to taphonomic pathways (Lee 2012). The deposited assemblage is inherently biased toward plant parts with a higher likelihood of discard, spillage, or storage, whereas plants consumed raw have little chance to become buried. Plant deposition also occurs through non-anthropogenic processes such as abiogenic (e.g., wind and water) and biogenic (e.g., animals and insects) transport (Minnis 1981). In the Great Basin, a primary non-human agent of plant introduction is the woodrat (*Neotoma* sp.), which consumes, caches, and constructs its home with a variety of plant taxa (Vaughan 1990). Rhode and Louderback (2007) provide a good discussion on this issue in rockshelter contexts specifically. We took great care to identify and separately excavate burrow fill and other disturbances during excavation. We did not observe any rodent disturbances within the sampled areas of the features.

Many variables affect the likelihood that plants will preserve to become part of the fossil assemblage. The Cave 5 East Block has some of the best preservation among the Connley Caves site. A variety of fragile organic materials, including textiles and coprolites, is preserved in the Middle and Late Holocene deposits there (Beck et al. 2004; McDonough 2019); however, organic preservation is not as good in the lower deposits, perhaps due to increased moisture or frost activity during Younger Dryas times. Therefore, the fossil assemblage analyzed here is largely composed of charred seeds and likely biased toward more resilient plant remains (i.e., hard seeds). Our sampled assemblage focuses on combustion areas where plant remains were

more likely to have preserved due to human activity and carbonization, and where we could more concretely define them as being the result of human activity.

We considered the ecology, density, spatial distribution, and ethnographic use of each taxon to evaluate whether it should be attributed to human use or natural processes (e.g., animal activity or seed rain). Woodrats and seed rain are unlikely to have introduced obligate wetland taxa, as the nearest marshland (> 1 km) exceeds ranges of woodrat foraging (< 500 m; Thompson 1982; Topping and Millar 1996) and most natural seed dispersal. Therefore, the presence of wetland plants in any significant amount within features is likely the result of human activity. To assess the origin of dryland taxa, we examined seed density and diversity throughout the site. We classified dietary association as “probable” when taxa have an NISP of five or greater and meet at least two of the following criteria: (1) density is much higher within than outside of features or the taxon is found only within features; (2) distance to the plant’s habitat exceeds the range of rodent foraging and natural seed rain; and (3) dietary use is ethnographically documented. Dietary association is “potential” if two criteria are met but the NISP is less than five. Plants that do not fulfil the two criteria are considered “unlikely” dietary constituents.

1.7.4. Quantification and Statistics

We considered fragments of seeds and other materials as individual specimens in the determination of the number of identified specimens (NISP) and used soil volumes to standardize samples for comparison. We computed ubiquity, richness, diversity, and evenness using Microsoft Excel. Ubiquity is expressed as a percentage determined by the number of samples in which a specific taxon is present divided by the total number of samples. Richness is the number of different taxa in a sample. The Shannon index (Shannon and Weaver 1949) is a common diversity index that incorporates richness to assess species homogeneity or

heterogeneity of a sample. A high H-value suggests a diverse and equally distributed community, whereas a lower value indicates a less diverse community. Equitability (V) measures the distribution of species, with zero signifying no evenness and one signifying complete evenness.

These measures are explained by the formulae,

$$H^1 = - \sum (p_i)(\ln p_i)$$

$$V^1 = H^1/(\ln S)$$

where H is the Shannon index, p_i is the proportion of the total sample represented by the species i , $\ln p_i$ is the natural logarithm of p_i , V is the evenness, and S is the total number of taxa in the sample (i.e., richness).

To assess the similarity between samples, we used the exploratory statistical technique of agglomerative hierarchical cluster analysis with Ward's method, which uses Squared Euclidean distance as a measure to create compact clusters with minimized variance. This exploratory statistical technique does not assume a normal distribution and treats each sample as an individual entity. The cluster analyses we completed looked at the cooccurrence of plant taxa that are “probable” and “potential” dietary constituents. Violin plots based on seed density (average NISP of seeds per liter) further explore variation among feature and column samples. We used R 4.0.1 (R Core Team 2020) software to conduct multivariate statistics and create plots.

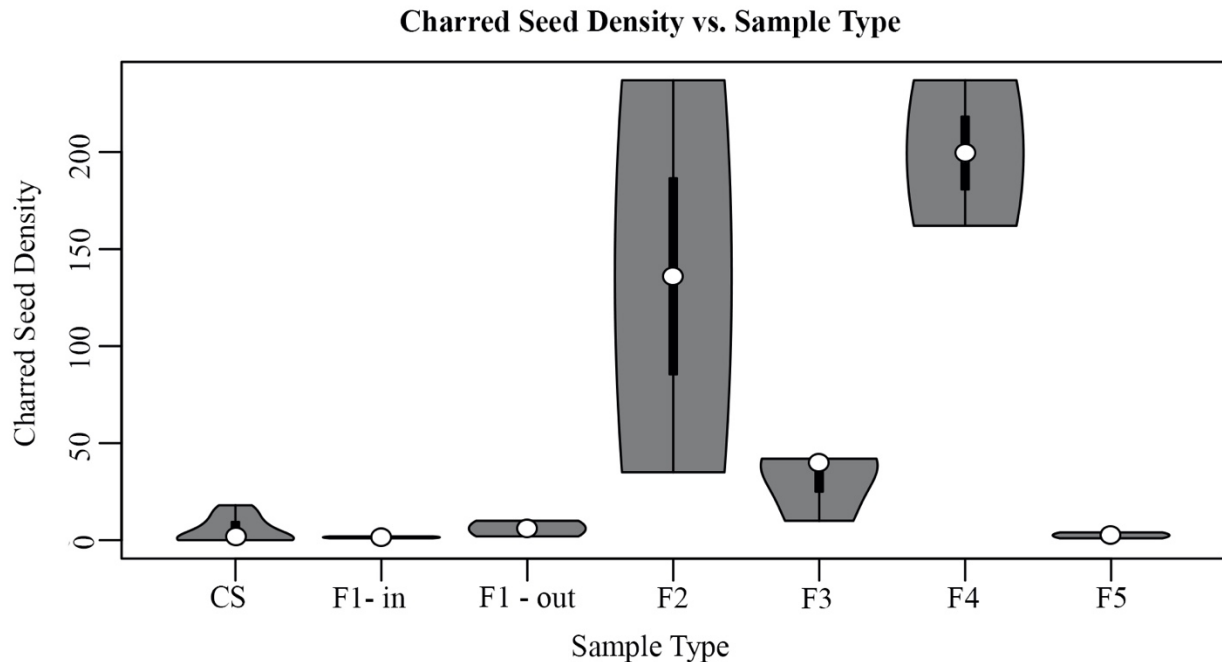


Figure 2.4. Violin plot of total charred seed density (average NISP per liter) by sample type. We normalized samples by volume and include the following types: column samples (CS, N = 17); inside Feature 1 (F1 – in, N = 2); outside Feature 1 (F1 – out, N = 2); inside Feature 2 (F2, N = 2); inside Feature 3 hearth (F3, N = 3); inside Feature 4 (F4; N = 2); and inside Feature 5 (F5, N = 2).

1.8. Results

1.8.1. Stratigraphy

Excavations at Connley Cave 5 revealed stratigraphy matching Connley Cave 4 (Jenkins et al. 2017) but provided more clarity about site-formation processes and confirmed the presence of a stratigraphic unit (LU3), which was observed in Cave 4 as laterally discontinuous (Figures 2.4 and 2.5; Appendix A, Table A.2). The late Pleistocene-Early Holocene archaeological record at Connley Cave 5 includes, from the bottom upwards, wind-blown and colluvial deposits spanning lithostratigraphic units (LU) 2 through 5. Descriptions of each LU can be found in the Table A.2.

Connley Cave 5 (35LK50)
Stratigraphic Framework

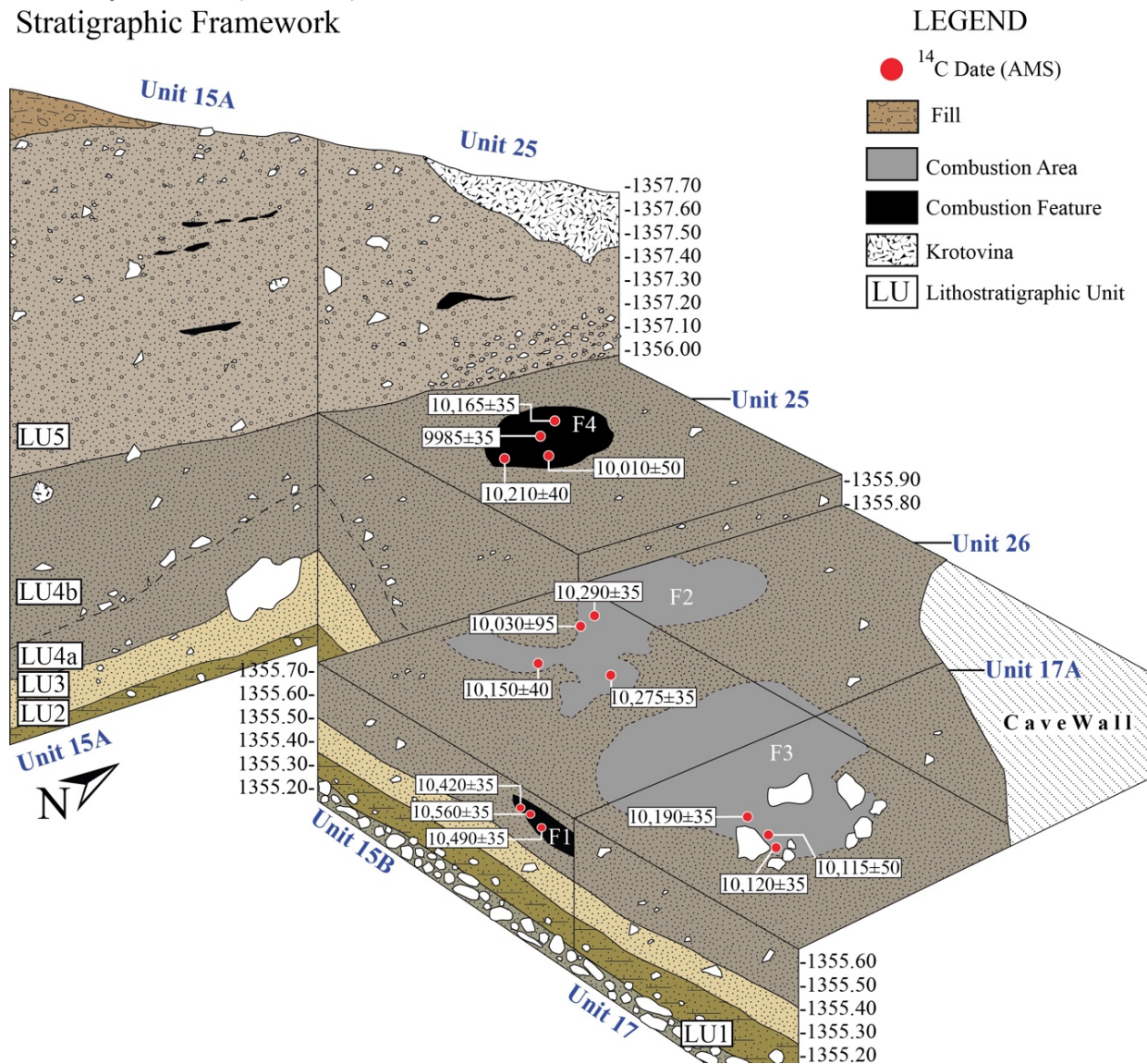


Figure 2.5. Perspective view of the Cave 5 excavation block showing features 1 through 4. Note that Feature 1 is displayed here ~20 cm farther south than its true placement (refer to Table 2.1 and Figure 2.3 for true provenience). Figure by Justin Holcomb.

Our previous hypotheses about the formation of LU2 in Cave 4 supposed that cementation within this unit was associated with the translocation of mineral-rich water (Jenkins et al. 2017), but ongoing micromorphological research has identified a cryogenic origin and due to the presence of freeze-thaw activity and ice compaction causing a permafrost zone during the

Younger Dryas (Holcomb et al. 2021). Micromorphological analysis of LU4a revealed the presence of weakly formed isobanded fabrics also associated with freeze-thaw activity including silt capping on coarser clasts (fine gravels, microlithics) and rounded vesicles typical of freeze-thaw activity. While these processes suggest some post-depositional alteration of the sediments and hearths preserved within LU4a, these effects are minimal as the presence of microscopic features typical of strong cryoturbation (e.g., frost heave, frost jacking, or gelifluction) are not present (e.g., silt coatings, vertical or aligned clasts, and lenticular structures) (Vliet-Lanoë and Fox 2010).

The five combustion features discussed in this paper are preserved within LU4a, 4b, and 5. Sedimentation outpaces pedogenesis at Connley Caves, which aided in the preservation of intermittent occupation activity at the site. The features are distributed both horizontally and vertically throughout the Cave 5 excavation block. Tables 2.1 and 2.2 list the elevation intervals for each feature and the stratum in which it occurs to demonstrate relative age within the profile. We currently interpret most of these as separate cultural occupations, with the exception of features 2 and 3, which occurred at similar elevations.

1.8.2. Feature Descriptions

Feature 1 (15B-HF-2) is a bowl-shaped hearth with intact bedding and firing structure as indicated by stratified charcoal wood fragments and ash above rubified sediment. Excavation Unit 15B bisected this hearth, and the eastern half of the feature is still preserved in the unexcavated levels of Unit 17. Feature 2 (15B-HF-1) is a combustion area characterized by irregular and widespread patches of ash, dispersed charcoal, and discolored and rubified sediment with diffuse boundaries. This combustion area may represent one or multiple hearths, a rake-out, or a combination of both obscured via natural (e.g., wind) or cultural (e.g., foot traffic)

processes. Feature 3 (17-HF-1) refers to a hearth area that includes a rock-lined hearth composed of nine cobbles arranged in a circle within Unit 17, as well as an area of concentrated charcoal expanding out from the rock ring toward the northwest and into Unit 15B. Similarity of the fill within the feature and the contiguous combustion area to the west suggests that some of the original contents of the hearth may have been removed and deposited outside of the rock-ring via wind or human activity (i.e., a rake-out). We separately analyzed samples from within (#1781, #1994) and outside of the rock ring (#2460) but consider them together as “Feature 3” due to the likelihood that their contents represent the same event. The possibility that these areas represent multiple events cannot be ruled out, and future studies may wish to interpret these samples separately. Feature 4 (25-HF-2) is an intact bowl-shaped hearth with a rubified base located in the center of Unit 25. Feature 5 (18-HF-1) is a shallow bowl-shaped hearth in the northeast quadrant of Unit 18.

1.8.3. Radiocarbon Dating

Table 2.1 lists 17 new radiocarbon dates on sagebrush (*Artemisia* spp.) charcoal from the five combustion features. All results are rounded following the conventions of Stuiver and Polach (1977) and calibrated with OxCal v4.4 (Bronk Ramsey 2009) using the IntCal20 curve (Reimer et al. 2020). Provenience information and further lab information can be found in Appendix A (Table A.3). All the dates for features 1, 2, and 3 internally overlap at 95.4% probability. The four dates from Feature 4 fall into two groups separated by ~150 radiocarbon years. Because Feature 4 is ~20 cm higher in elevation than Feature 3, the younger two dates (PSUAMS#5007 and D-AMS 30300) appear to accurately represent the age of the feature. PSUAMS#5247 is ~400-300 radiocarbon years older than the other two dates from Feature 5, suggesting it is the outlier of the three. Because all dates are on charcoal samples from

undisturbed contexts within cultural combustion features, bioturbation is not likely the cause of the disagreements. Instead, inconsistencies are more likely explained by either the use of ancient wood from nearby woodrat middens as fuel, reuse of old cultural features later in time, or statistical scatter. We strongly favor the first possibility because features 4 and 5 are discrete hearths that are elevationally or stratigraphically younger in age than the other features. To summarize, the radiocarbon results indicate that Feature 1 dates to ~12,500 cal BP; Feature 2 activity dates to between ~12,000 and 11,800 cal BP; Feature 3 dates to ~11,800 cal BP; Feature 4 dates to ~11,500 cal BP; and Feature 5 dates to ~10,200 cal BP.

1.8.4. Archaeobotanical Analysis

Analysis of eleven sediment samples from the five combustion features yielded charred seeds (NISP = 767) and uncharred seeds (NISP = 359) (Table 2.2, Figures 2.6 and 2.7; see Appendix A, Table A.4, for individual sample counts). Represented among the charred seeds were 21 unique plant taxa—18 of which are known edible plants included in diets of Great Basin and California Indigenous groups (Table 2.3, see Appendix A, Table A.5, for the Klamath, Modoc, and Northern Paiute plant names). Other constituents include charcoal, charred starchy and fruity plant tissue, sclerotia (mycorrhizal fungal bodies), sap, bone, eggshell, feathers, debitage, and two bone eyed-needle fragments.

Connley Cave 5
Unit 25 West

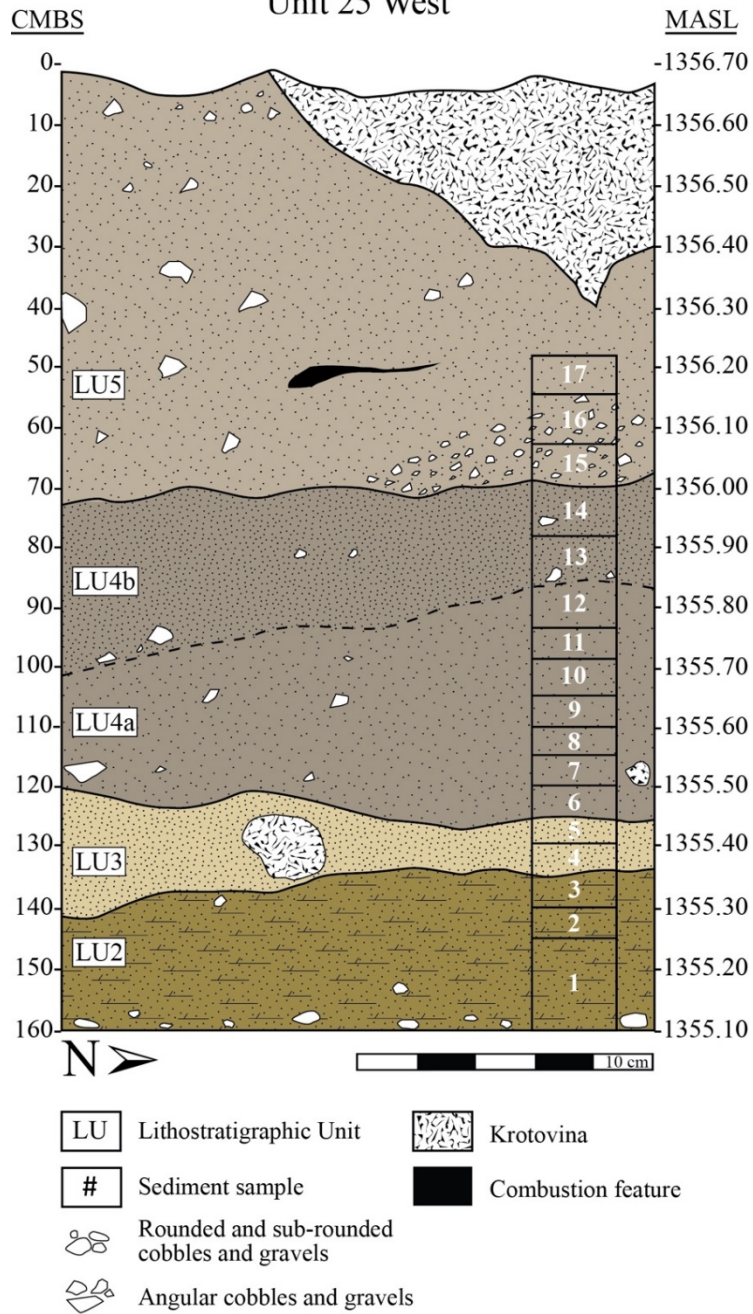


Figure 2.6. Stratigraphic interpretation of the west profile of Unit 25 with corresponding lithostratigraphic units (LU). Stratigraphic descriptions of each LU are found in Appendix A (Table A.2). Figure by Justin Holcomb.



Figure 2.7. Examples of seeds (a-c, e-w) and other macrobotanicals (d, w) recovered from combustion features: peppergrass; (b) cf. sedge.; (c) knotweed family (Polygonaceae) endosperm; (d) possible bud fragment; (e) phacelia; (f) mare's tail; (g) dodder; (h) spikerush.; (i) dropseed sandgrass; (j) mallow family; (k) whitestem blazingstar; (l) amaranth family; (m) goosefoot; (n) saltbush; (o, p) cf. seepweed.; (q) buckwheat; (r) cattail; (s-u) sagebrush; (v) rush; (w) sclerotia.

Table 2.2. Feature sample data.

	Feature 1 (15b-HF-2)	Feature 2 (15b-HF-1)	Feature 3 (17-HF-1)	Feature 4 (25-HF-2)	Feature 5 (18-HF-1)	Feature Ubiquity	Column Ubiquity
Elevation (cm below 1356.5 m ASL)	84-93	63-74	65-75	51-58	61-63	-	-
Volume (L)	2	2	3	2	2	-	-
Seed (NISF): Total; Charred	3; 3	579; 272	94; 88	445; 399	5; 5	-	-
Charred Seed Density/1 L	1.5	136	29.3	199.5	2.5	-	-
Shannon Index	0.637	1.4	1.717	1.603	0.95	-	-
Species Richness	2	14	14	14	3	-	-
Evenness	0.918	0.531	0.651	0.607	0.865	-	-
<i>Wetland Seeds^{a, b}</i>							
Cattail	-	7	-	10	-	40	6
Cattail, UNCH	-	307	-	23	-	40	-
Mare's tail	-	1	-	-	-	20	-
Rush-type	-	-	-	2	-	20	-
cf. Sedge	-	-	-	-	1	20	-
<i>Dryland Seeds</i>							
Amaranth family	2	120	40	203	3	100	41
Buckwheat	-	18	1	25	-	60	-
Dropseed	-	1	-	4	-	40	6
Goosefoot	-	14	5	5	1	80	35
Grass family	-	-	1	1	-	20	6
cf. Mallow	-	1	-	-	-	20	-
Peppergrass	-	2	1	13	-	60	-

	Feature 1 (15b-HF-2)	Feature 2 (15b-HF-1)	Feature 3 (17-HF-1)	Feature 4 (25-HF-2)	Feature 5 (18-HF-1)	Feature Ubiquity	Column Ubiquity
Pigweed, UNCH	-	-	1	-	-	20	-
cf. Ricegrass, caryopsis	-	-	1	-	-	20	-
Sagebrush	-	1	1	12	-	60	-
Saltbush	-	19	8	5	-	60	6
cf. Seepweed	-	11	1	6	-	60	-
Sunflower family	-	-	1	-	-	20	-
Whitestem blazingstar	-	-	-	1	-	20	-
cf. Phacelia	-	-	1	-	-	20	-
<i>Wetland or Dryland Seeds</i>							
Dodder	-	-	1	1	-	40	6
Dodder, UNCH	-	-	-	8	-	20	24
Knotweed	-	-	2	-	-	20	-
Spikerush	-	1	-	-	-	20	-
cf. Viola	-	2	-	-	-	20	-
Unidentified	1	74	24	111	-	80	35
Unidentified, UNCH	-	-	5	15	-	40	6
<i>Other Vegetal Material</i>							
Charcoal (g)	11.85	25.99	18.76	6.71	7.24	100	65
Fungi sclerotia, CH	-	-	8	1	-	40	-
Fungi sclerotia, UNCH	-	-	6	-	-	20	-
Plant tissue - starchy	-	P	P	P	-	80	-
Plant tissue - fruity	-	-	P	P	-	60	-
Other	-	sap	bud, nutlet	-	-	-	-

	Feature 1 (15b-HF-2)	Feature 2 (15b-HF-1)	Feature 3 (17-HF-1)	Feature 4 (25-HF-2)	Feature 5 (18-HF-1)	Feature Ubiquity	Column Ubiquity
<i>Fauna and Artifacts</i>							
Bone (g)	4.79	20.46	54.42	49.83	4.24	100	94
Fish vertebra	13	108	71	427	16	100	59
Eggshell (E); feather (F)	-	E	E	E; F	E	80	-
Debitage	67	275	1488	121	28	100	71
Bone needle	-	1	-	1	-	40	-

The most ubiquitous taxa (present in > 25% of samples) from the features are goosefoot (*Chenopodium* sp.), saltbush (*Atriplex* sp.), peppergrass (*Lepidium* sp.), seepweed (*Suaeda* sp.), buckwheat (*Eriogonum* sp.), and cattail (*Typha* sp.). Amaranth family (Amaranthaceae) and cattail seeds have the greatest abundance, followed by buckwheat and sagebrush seeds. Uncharred seeds found within features are predominantly cattail (91.9%), followed by smaller amounts of dodder (*Cuscuta* sp.) (~2.1%), pigweed (*Amaranthus* sp.) (< 1%), and unidentified fragments (5.6%). Charred-seed density is highly variable between features, ranging from an average of 1.5 seeds per liter in Feature 1 to 199.5 seeds per liter in Feature 4. Features 2, 3, and 4 have high richness and diversity values, whereas Features 1 and 2 have low richness (see Table 2.2). Column samples yielded a total of 40 charred and 3 uncharred seeds (Appendix A, Table A.6). Plant taxa present in the column samples include seeds of bulrush-type (*Juncus*-type), cattail, dodder, dropseed (*Sporobolus* sp.), goosefoot, and saltbush. Additional seeds from the grass and amaranth families could not be identified to genus. Column samples did not contain any charred starchy tissue, fruity plant tissue, or formed tools. When normalized by volume, the density of charred seeds in non-feature samples ranged from zero to approximately 13 per liter (excluding sample C14, which was < 25 cm from Feature 4, and C17, which was disturbed), suggesting that natural seed deposition is characterized by low density and low diversity.

When compared, as in the violin plots in Figure 2.8, features 2, 3, and 4 have significantly higher seed densities than features 1 and 5. Cluster dendrograms identify features 2 and 4 as clear outliers, whereas features 1 and 5 group closely together (Figure 2.9). When analyzed with the column samples, features 2 and 4 remain most dissimilar, whereas features 1 and 5 group closely with the column samples (Figure 2.9). Feature 3 samples are dissimilar from the column samples, but less so than are features 2 and 4. Overall, this suggests that the

archaeobotanical assemblages of features 2, 3, and 4 are inconsistent with natural patterns of seed deposition at the site, whereas those from features 1 and 5 are consistent with natural seed deposition.

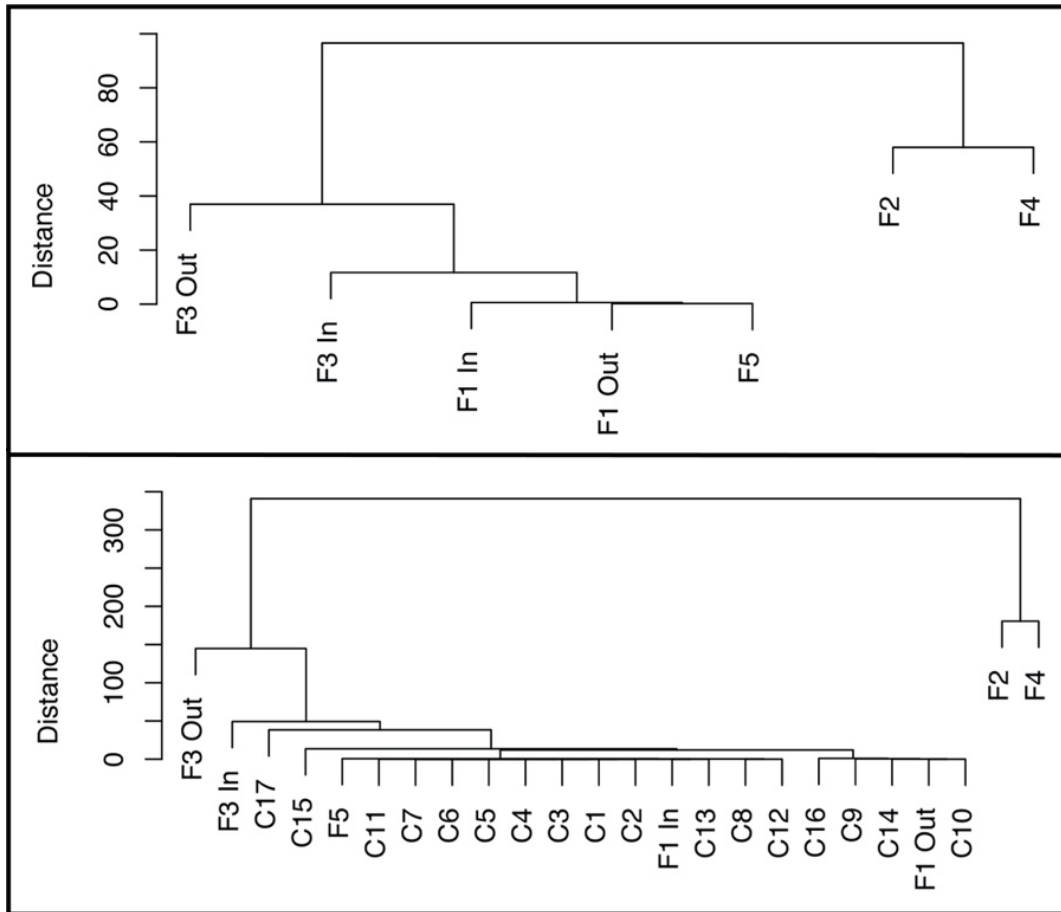


Figure 2.8. Cluster dendrograms of features using NISP of seeds considered “probable” and “possible” dietary constituents (amaranth family, blazingstar, buckwheat, cattail, dropseed, goosefoot, grass family, knotweed, mallow family, phacelia, pigweed, rush, sagebrush, saltbush, sedge, seepweed, spikerush, sunflower family, peppergrass, and viola seeds). We normalized samples to account for volumetric differences.

1.9. Feature Interpretations

Our analysis reveals that humans visiting Connley Caves during the Younger Dryas foraged and consumed plants during multiple periods of site use. Based on our evaluative scheme, probable dietary taxa include buckwheat, cattail, goosefoot, peppergrass, saltbush, and

seepweed (see Table 2.3, Figure 2.10). Sagebrush seeds meet two of our criteria; however, their abundance within features is probably related to use as fuel. Potential dietary taxa include whitestem blazingstar (*Mentzelia albicaulis*; partially charred), knotweed, ricegrass (cf. *Eriocoma hymenoides*), phacelia (cf. *Phacelia* sp.), pigweed, rush, sedge, spikerush (*Eleocharis* sp.), violet (*Viola* sp.), and possibly seeds of the mallow (cf. Malvaceae) and sunflower (Asteraceae) families. Although dropseed is not commonly mentioned in the ethnographies we consulted for Indigenous groups of the Great Basin and California, dropseed could be referred to under the name *Agrostis airoides* in an ethnography of the Owen's Valley Paiute (Steward 1938), and seeds of this plant are consumed by Indigenous groups elsewhere in North America (Castetter and Opler 1936; Moerman 1998; Reagan 1929). Dropseed (Stevenson 1915) and several other taxa (e.g., cattail, rush, spikerush) are also used in textile production and may represent other economic activities. Below, we interpret each feature individually with consideration of the associated non-plant materials. Examples of lithic and osseous artifacts associated with each feature can be found in the Appendix A (Figure A.3).

Table 2.3. Names, traditional uses, plant communities (PC), seasonal availability, and dietary association of taxa from features.

Family	Genus/Species	Common Name	Parts Used ^a	Use	Cooking Process ^a	PC ^b	Seasonal Availability ^c	Dietary Assoc. (Criteria Met)	Presence at Other Pleistocene-Age WST Sites
Amaranthaceae	<i>Atriplex</i>	Saltbush/shadscale	Root, seed	F, M	Ground, raw, parched	LOW	Fall-winter	Probable (1, 3)	Paisley (probable), Bonneville Estates (probable)
Amaranthaceae	<i>Amaranthus</i>	Pigweed	Seed	F	Ground	LOW	Fall	Potential (1, 3)	Paisley (coprolite, probable)
Amaranthaceae	<i>Chenopodium</i>	Goosefoot	Leaves, seed	F, M	Ground, parched, raw	LOW	Fall	Probable (1, 3)	Bonneville Estates (probable); Wishbone (potential)
Amaranthaceae	<i>Suaeda</i>	Seepweed	Leaves, seed	F, M	Boiled, ground, parched, raw	LOW	Fall	Probable (1, 3)	-
Asteraceae	<i>Artemisia</i>	Sagebrush	All	F, M, Te, To	Burned, infused, pounded, steeped	LOW, UPL	Summer	Probable (1, 3) ^d	Bonneville Estates (potential)
Brassicaceae	<i>Lepidium</i>	Peppergrass	Leaves, seed*	B, F	Boiled, dried, parched, raw	-	Summer	Probable (1, 3)	-
Plantaginaceae	<i>Hippuris</i>	Mare's tail	N/A			WET	Summer-fall	Unlikely (2)	-
Convolvaceae	<i>Cuscuta</i>	Dodder	Stem	M	Powdered, raw	-	Year round	Unlikely (0)	-
Cyperaceae	<i>Cyperus</i>	Sedge	Tuber	F	Cooked, ground, raw	WET	Summer-fall	Potential (1, 2) ^d	-
Cyperaceae	<i>Eleocharis</i>	Spikerush	Bulbs, sap	F	Raw	WET	Summer-fall	Potential (1, 2)	-
Hydrophyllaceae	<i>Phacelia</i>	Phacelia	Leaves, root	F, M	Infused	-	Summer-fall	Potential (1, 3)	Paisley (potential)
Juncaceae	<i>Juncus</i> -type	Rush	Seed, stem	B, C, F, Te	Fermented, raw	WET	Summer	Potential (1, 3) ^d	-
Loasaceae	<i>Mentzelia albicaulis</i>	Whitestem blazingstar	Seed	F, R, S	Dried, ground, parched	-	Fall	Potential (1, 3)	-

Family	Genus/Species	Common Name	Parts Used ^a	Use	Cooking Process ^a	PC ^b	Seasonal Availability ^c	Dietary Assoc. (Criteria Met)	Presence at Other Pleistocene-Age WST Sites
Malvaceae	<i>Sphaeralcea</i>	Desert mallow	Leaves, root	M, P	Cooked, ground, infused, pounded	-	Summer	Potential (1, 3)	-
Poaceae	<i>Eriocoma hymenoides</i>	Indian ricegrass	Seed	F, R, S	Ground, parched, pounded	LOW	Summer	Potential (1, 3)	Paisley (probable), Bonneville Estates (probable)
Poaceae	<i>Sporobolus</i>	Dropseed	N/A			LOW	Summer-fall	Potential (1, 3)	Bonneville Estates (probable)
Polygonaceae	<i>Eriogonum</i>	Buckwheat	Leaves, root, seed, stem	B, F, M	Pounded, raw, tool	LITH	Summer	Probable (1, 3)	-
Polygonaceae	<i>Polygonum</i>	Knotweed	Seed	F	Ground, parched	UPL	Summer-fall	Probable (1, 3)	-
Typhaceae	<i>Typha</i>	Cattail	All	F	Boiled, ground, parched, raw	WET	Summer-fall	Probable (1, 2, 3) ^d	Paisley (coprolite, probable), Bonneville Estates (potential)
Violaceae	<i>Viola</i>	Violet	-	M	N/a	-	Summer	Potential (1, 3)	-

^a Traditional uses and cooking process are based on ethnographic data from Indigenous groups of Oregon, Nevada, Utah, and California: beverage (B), candy (C), food (F), relish (R), sauce (S), textile (Te), and tool (To).

^b Habitat classification is based on plant communities (PC) in the Fort Rock basin by Prouty (1994): wetland (WET), lowland (LOW); upland (UPL), and lithosol (LITH).

^c Seasonal availability is based on data from USDA (2014) (dark grey indicates greatest availability and light grey indicates possible availability).

^d Economic use could be non-dietary (e.g., fuel source or textile construction).

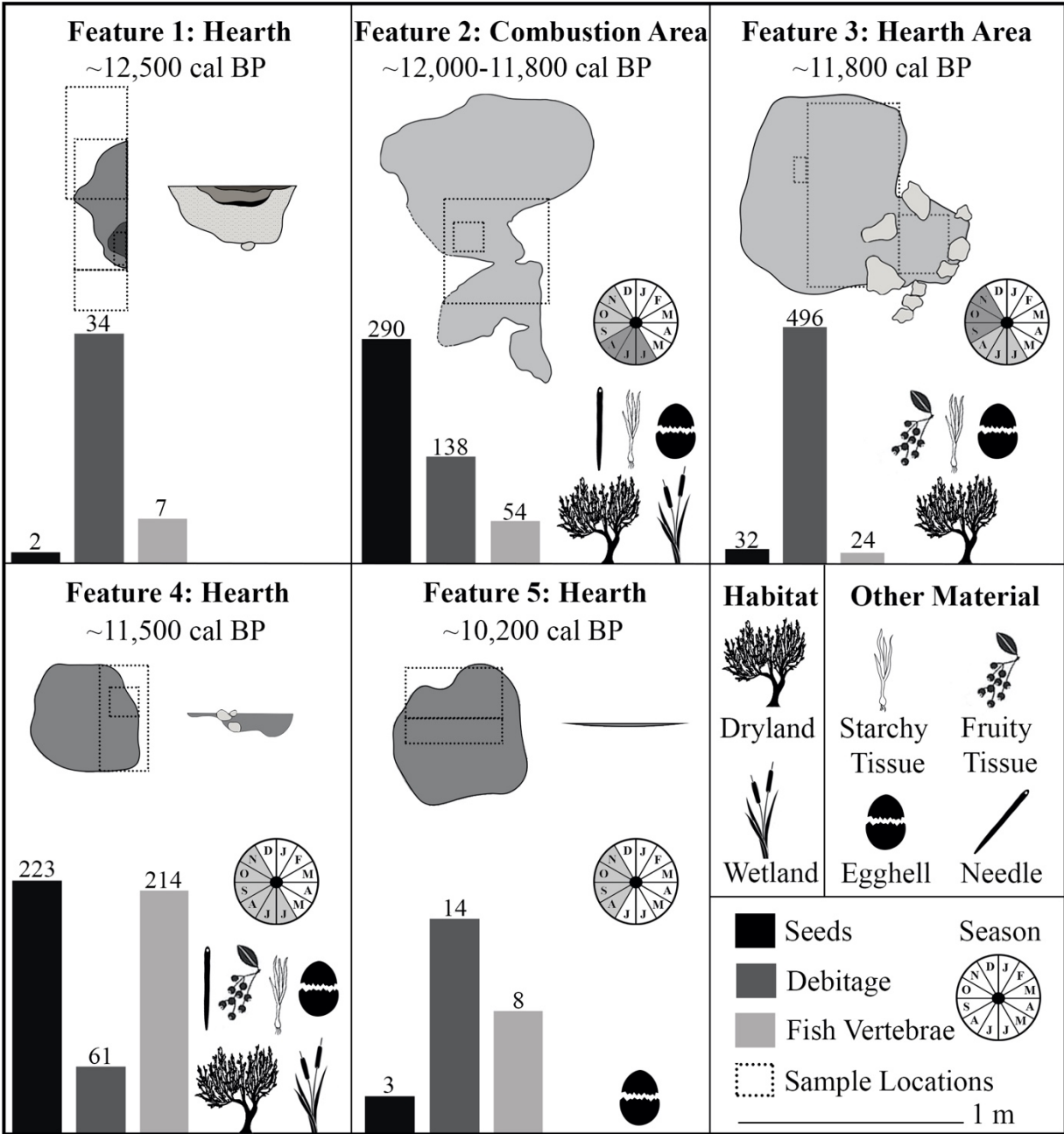


Figure 2.9. Summary of hearth contents. Bar charts represent average NISP per liter and include all seeds recovered from features. Sample locations reflect the maximum dimensions within the feature, except for Feature 1 for which we also sampled outside of the hearth.

1.9.1. Feature 1 (~12,500 cal BP)

Feature 1 did not produce compelling evidence for dietary plant use. Densities of charred seeds inside (n = 3) and outside (n = 12) of the hearth are slightly lower than the density observed in the column samples of corresponding elevation. Low density, diversity, and richness indices of plant remains in those samples suggest that they are the result of natural, rather than cultural processes. A paucity of plant remains precludes interpretation of season or foraging range; however, the lack of sagebrush seeds, the primary fuel taxa in the hearth, suggests occupation during a season other than late summer/early fall. The densities of debitage, bone, and fish vertebrae are also low relative to other features.

1.9.2. Feature 2 (~12,000- 11,800 cal BP)

The botanical remains from the Feature 2 combustion area may represent multiple activities or even occupation events, therefore providing a broader view of human behavior than assemblages from the discrete hearths. Samples from the Feature 2 area have high seed density, diversity, and richness measurements (Table 2.3). Based on abundance and ethnographic uses, the presence of buckwheat, cattail, goosefoot, saltbush, and seepweed seeds suggest subsistence activities. The seeds of dropseed, mallow, mare's tail, sagebrush, spikerush, peppergrass, and violet may also be economic but are present in low quantities. Small fragments of charred starchy and fruity tissue were also present and may represent use of geophytes or fruits. There is a greater diversity of summer-seeding taxa but greater abundance of fall-seeding taxa. Because the combustion area may be a palimpsest of multiple site visits, it is unclear whether people foraged in multiple habitats during a single occupation in the late summer/early fall, or during multiple visits throughout summer and fall.

Feature 2 has the highest density of charcoal of any sample and an unusually high density of fish vertebrae. The average density of fish vertebrae in Feature 2 (54 per liter) is much higher than in features 1, 3, and 5, but slightly lower than in the stratigraphically corresponding column sample (C13, 88 per liter), so it is currently equivocal whether they represent consumption. We also recovered the proximal fragment of a bone eyed needle within this feature (Figure 2.7a).



Figure 2.10. Examples of other hearth constituents: (a) bone eyed needle (2556-2530); (b) bone eyed needle eye (2556-1150); (c) charred and fragmented Amaranthaceae seeds; (d) fish vertebrae from Feature 4; (e) example of charred starchy tissue; (f) eggshell fragments (scale bars are 1 mm).

Overall, the constituents from Feature 2 show that people foraged for diverse plants in both wetland and dryland habitats and suggest that they may have also fished and sewed.

1.9.3. Feature 3 (~11,800 cal BP)

The Feature 3 hearth area provides a narrower view of behavior than Feature 2 but may also represent multiple uses or events. The rock ring demonstrates some level of hearth preparation, which could signal prolonged feature use—although the tool assemblage directly around the feature is relatively small. The combustion area that extends outside the rock ring probably represents a rake-out or, less likely, hearth contents displaced by aeolian processes. Analysis of the contents revealed very similar constituents within and outside of the rock ring, suggesting that they reflect similar activities and possibly the same event. As such, we consider them together as one hearth area.

Feature 3 contains a high density of economic plants known from other Younger Dryas sites, such as goosefoot and saltbush seeds. Lesser amounts of buckwheat, peppergrass, phacelia, seepweed, grass family, and sunflower family seeds may also reflect subsistence. Sagebrush and dodder seeds are more likely related to medicinal plant use or fuel, rather than subsistence. Both plants are important to the Paiute and Klamath for their medicinal properties (Coville 1897; Mahar 1953; Murphey 1959; Park and Fowler 1989; Spier 1930; Train et al. 1941). Sagebrush is also a primary source of fuel at Connley Caves and is one of many plants that dodder parasitizes (Hitchcock and Cronquist 2018:447). Charred starchy and fruity tissue, one charred nutlet fragment, and two charred bud fragments could also be subsistence related.

All the botanical taxa in Feature 3 grow in dryland contexts, primarily in lowland habitats with minor representation of lithosol (buckwheat) plant communities. All four taxa from the amaranth family seed in fall, phacelia species seed between summer and fall, and the remaining

three taxa (buckwheat, sagebrush, and peppergrass) seed in summer. The majority of seeds are available closer to fall, indicating a very late summer or fall occupation. Overall seed density and diversity for Feature 3 is higher than features 1, 5, and most column samples, suggesting consumption, but perhaps in a more limited capacity than reflected in features 2 and 4. Bone, charcoal, and debitage densities are higher in the samples collected outside of the rock ring than the sample within it (Appendix A, Table A.4). Microdebitage is high in all samples of Feature 3 and greatest (633 pieces per liter) in the northwestern quadrant of the feature area. Taken together, the contents of Feature 3 suggest that people engaged in a variety of activities during their stay, including plant foraging in dryland habitats during late summer or early fall.

1.9.4. Feature 4 (~11,500 cal BP)

Feature 4 provides further evidence of wetland and dryland foraging. Feature 4 has the highest charred seed density (~200 per liter) of all samples analyzed. Based on abundance, we consider buckwheat, cattail, peppergrass, goosefoot, saltbush, and seepweed to be economic. The botanical assemblage of Feature 4 is dominated by seeds of the amaranth family (49% seed total), but over 90% of these cannot be identified beyond family level due to high fragmentation and “popping” (see Figure 2.7c). This taphonomy could be the result of seed processing and parching. Additional seeds that may be subsistence related but occur in lower quantities include blazingstar, dropseed, and rush. Rush-type and blazingstar seeds are not present in any other feature samples, and the only other occurrence of dropseed is from C17. Dodder and sagebrush seeds are also present in Feature 4, and our interpretation of their presence is the same as in Feature 3, that they are most likely related to use as fuel or medicine. There is a nearly even split between the number of taxa that seed in the summer versus the fall, with four appearing in the

summer, four appearing in the fall, and two that seed from summer through fall. This suggests an occupation during late summer/early fall created Feature 4.

Feature 4 also yielded a very tiny proximal fragment of a bone eyed needle, and the lowest charcoal and highest fish-vertebrae densities of any feature. The needle fragment is less than 2 mm long, broken through the middle of the eye (see Figure 2.7b). The abundance of fish vertebrae (~213 NISP per liter) suggests fishing activities and lends further support for wetland exploitation. Overall, the low occurrence of debitage relative to the high density of charred seeds and abundance of fish vertebrae and other faunal remains strongly suggests Feature 4 is a cooking feature. The presence of both wetland and terrestrial plant taxa in the same discrete hearth indicates that cave occupants exploited a range of resources from multiple habitats within a short period of time.

1.9.5. Feature 5 (~10,200 cal BP)

Feature 5 stands out for having very few plant remains and low amounts of charcoal. It also has the lowest bone, fish, and debitage densities and is the only feature without any eggshell. The botanical assemblage is composed of three amaranth-family seeds, one sedge seed, and one grass seed. These taxa typically seed in very late summer or fall, but their low occurrences prohibit any strong interpretations regarding patterns of seasonality or foraging zone.

1.10. Discussion

1.10.1. Paleoindian Plant Use at Connley Caves

Paleoethnobotanical analysis and radiocarbon dating of cultural features from stratified contexts at Connley Cave 5 confirm that humans recurrently visited the site and consumed plants throughout the Younger Dryas and very earliest Holocene. The oldest (Feature 1, ~12,500 cal

BP) and youngest (Feature 5, ~10,200 cal BP) features contained very few archaeobotanical remains and may represent events in which plants were of little importance (e.g., logistical stopovers or hunting forays) or may reflect winter or spring visits which are harder to detect through archaeobotanical analysis. Few plants are available in the winter months and those that are harvested in spring are less likely to preserve (e.g., fresh shoots, leafy greens, roots). Features 2, 3, and 4 produced strong evidence for plant use but reflect different foraging habitats and variable lengths of stay. Feature 2 contained both wetland and dryland taxa indicative of variable foraging zones, although this combustion area may be a palimpsest of multiple events. As an intact hearth, Feature 4 offers a narrower view of site use, and, given the cooccurrence of high-density fish vertebrae with wetland and dryland plants, suggests that visitors foraged and fished in multiple habitats within a short interval of time. The Feature 3 hearth area produced a range of dryland plants but lacked evidence of wetland use. Representation of both wetland and dryland resources in Features 2 and 4 may reflect divisions in labor, while other features may reflect converging foraging goals. Environmentally, the presence of wetland plant and animal taxa suggests that Paulina Marsh was established and productive during the Younger Dryas, whereas the absence of juniper macrofossils indicates that the vegetation surrounding the caves may have been more open than it is today.

In light of these data, we can begin to reevaluate the traditional narrative of the archaeology of Connley Caves. Based on his excavations of various rockshelter sites in the Fort Rock Basin, Bedwell (1970, 1973) proposed that human activity was high during the PHT and that groups were attracted to Connley Caves by the biotic productivity of the nearby lake, marshland, and grassland habitats. Though Bedwell emphasized the “seemingly high degree of adaptation to a lake economy”, which formed the basis of his Western Pluvial Lakes Tradition

hypothesis, he also proposed that foraging objectives at Connley Caves were diverse and included both land- and water-adapted fauna (Bedwell 1973:158). From the perspective of plant foraging, the general idea of Bedwell's model is only partially supported. Wetland exploitation is clearly represented in features 2 and 4, but dryland plant foraging is ubiquitous. Future analyses of the faunal assemblage will ultimately provide clarity on accuracy of the WPLT hypothesis.

More recent considerations of Bedwell's findings led some researchers to hypothesize that cultural occupation may have been more intensive during the Early Holocene than during the Younger Dryas (Goebel et al. 2011). Our findings, however, confirm that the site was repeatedly and primarily used throughout the Younger Dryas. This is clearly demonstrated by the significant drop off in occupational evidence following 11,500 cal BP (Feature 4), with only a single cultural feature (Feature 5) and a small amount of cultural material in the Early Holocene deposits relative to the Younger Dryas deposits. Still, evidence for plant use is not ubiquitous and cannot yet be shown to have occurred before the late Younger Dryas (i.e., before 12,000 cal BP). During the late Younger Dryas and earliest Holocene, we find evidence of dryland plant use in three features and strong support for wetland foraging in two. Overall, this study suggests that people foraged for dryland and wetland plants—but not always both at the same time—during different periods of site use.

Researchers have also speculated about seasonality of site use. Jenkins and colleagues (2002) proposed the caves may have served as a winter camp(s) due to the availability of migratory waterfowl, migrating artiodactyl herds, and marsh plants. Grayson (1979:446) considered several seasonal scenarios based on the sex ratio of sage-grouse (*Centrocercus urophasianus*) in the pre-Mazama faunal assemblage of nearby Cave 4, alternatively hypothesizing that humans predated on: (1) separate male and female flocks in the uplands

during the winter; (2) male flocks and dispersed females in the uplands during late spring; or (3) birds that went to drink at Paulina Marsh between late fall and early spring. Seasonal indicators from features 2, 3, and 4 suggest occupations during the late summer to early fall, which is not entirely consistent with any of the prior predictions. The paucity of charred seeds in features 1 and 5 could reflect winter or spring visits, events in which plants were unimportant, or both.

Our first look at the archaeobotanical assemblages of these five features provides important insights on human behavior during the PHT at Connley Cave 5, but we must also recognize the limitations of this study. Due to issues of taphonomy, the botanical remains in our sampled assemblage most likely reflect only a fraction of original plant use. Our view is likely biased toward plant taxa and parts that are more durable and have greater opportunity to become discarded and/or carbonized. Additionally, we have examined just one area of a much larger site complex. Continued investigations in the site's other shelters and analysis of other dietary evidence (e.g., zooarchaeological) will provide a more holistic picture of human activity and subsistence.

1.10.2. Contribution to the Paleoindian Subsistence Record

Archaeobotanical analyses of the assemblages from three Connley Cave 5 features reaffirm the inclusion of plants in the diet of Paleoindian groups and contribute new taxa to the known PHT food economy. Of the 19 taxa that we interpret as probably or potentially dietary, nearly half have been found in other Younger Dryas-aged hearth features or coprolites in the Great Basin associated with WST technology (Table 2.3). These include seeds of cattail, dropseed sandgrass, goosefoot, pigweed, ricegrass, rush, sagebrush, saltbush, and the sunflower family. Seeds of the amaranth family appear in cultural contexts at Paisley Caves, Bonneville Estates Rockshelter, and Wishbone. Respective analysts interpreted grass seeds as economic at

both Bonneville Estates (dropseed and ricegrass) and Paisley (ricegrass). Hearths at these two sites contained other members of the mustard family as well. Rhode and Louderback (2007) attributed the presence of cattail seeds in hearths at Bonneville Estates to use of fluff as fire starter; however, the recovery of cattail seeds from Younger Dryas and Early Holocene coprolites at Paisley shows that dietary use should not be ruled out. Northern Paiute groups toasted, winnowed, and consumed cattail seeds (Fowler 1990, 1992; Park and Fowler 1989), as did people staying at Connley Caves during the Middle and Late Holocene, based on the high density (~1000 per gram) of cattail seeds in coprolites from Cave 5 (McDonough 2019). In sum, archaeobotanical data from Connley Caves and other Pleistocene-aged sites indicate that amaranths, grasses, mustards, and cattail were important and perhaps even staple plant foods for WST groups living in the Great Basin region during the late Younger Dryas and earliest Holocene.

New additions to the known Pleistocene plant-food economy include buckwheat, seepweed, and peppergrass. Buckwheat and seepweed are important economic plants to the Klamath, Paiute, and Modoc (Chamberlin 1911; Coville 1897; Fowler 1992; Kelly 1932; Park and Fowler 1989; Ray 1963; Spier 1930; Train et al. 1941), and peppergrass is used by the Kawaiisu of California and many other Indigenous groups throughout North America (Moerman 1998; Zigmond 1981). Buckwheat seeds are eaten parched, ground, or raw, and other parts of the plant have medicinal value (Helzer 2001; Train et al. 1941). Seepweed is also a well-known plant food that has been found in other archaeological contexts throughout the Great Basin, including Middle and Late Holocene sites in the Fort Rock Basin (Cummings 2004; Helzer 2001). Kennedy (2018) found both buckwheat and seepweed seeds in Early Holocene-aged hearths at Paisley Caves. Peppergrass is a variety of mustard that has been found in Great Basin

coprolites (e.g., Hogup Cave; Fry 1970, 1976) and hearths (e.g., Hidden Cave [Rhode 2003, 2008]; and Camels Back Cave [Schmitt and Madsen 2005]), but this is its first appearance in late Pleistocene features.

Other possible additions to the current record of Pleistocene plant use include blazingstar, knotweed, mallow family, phacelia, spikerush, and violet. All of these plants have known dietary and/or medicinal uses; however, with the exception of blazingstar and knotweed, many of those uses focus on the underground or leafy parts of the plant, rather than the seeds (Chamberlin 1911; Coville 1897; Kelly 1932; Murphey 1959; Park and Fowler 1989; Steward 1933; Train et al. 1941). Some of these plants, such as mallow, phacelia, and violet, produce relatively few seeds compared to weedy taxa (e.g., many grass and amaranth species). Due to preparation strategies and scale of seed production, some of these seed taxa would have less opportunity to be introduced and carbonized within hearths. Nevertheless, all these plants have been recovered from Holocene-aged archaeological contexts in the northern Great Basin (Connolly et al. 2015; Dexter 2010; Kennedy 2018; Kennedy and Smith 2016; McDonough 2019; Prouty 2004; Puseman and Yost 2011; Sanford 1983; Stenholm 1994), and a number of them are known from Paisley Caves, including low amounts of mallow ($n = 2$), phacelia ($n = 1$), and rush ($n = 1$) seeds from undated cooking features in Cave 5 and phacelia ($n = 2$) seeds in a Cave 2 hearth dating to ~11,390 cal BP. At least one of those Cave 5 features may have been an earth oven, based on the presence of charred starchy tissue and charred seeds of the lily (Liliaceae) family (Kennedy 2018). Though they have not been directly dated, Paisley Cave 5 hearths are likely Pleistocene in age based on their stratigraphic positions. The presence of blazingstar, knotweed, mallow family, phacelia, spikerush, and violet in the Connley Caves features may be related to economic use, but we consider this association as “potential” due to their low representation.

In addition to the paleoethnobotanical results, our study offers insights on other aspects of Paleoindian subsistence. Feature 4 provides the clearest evidence for wetland exploitation, including wetland plants and high density of fish vertebrae. In the Great Basin, Blong and colleagues (2020) recovered fish remains from a ~12,200 cal BP coprolite at Paisley Caves 2, and in the Snake River Plain of Idaho the Buhl Woman's isotopic signatures suggest she consumed anadromous fishes (Green et al. 1998; Jazwa et al. 2021). Eisllet's (1997) analysis of boli from the abdominal cavity of Burial #2 at Sprit Cave, Nevada identified abundant fish remains (NISP = 697) dating to 10,500 cal BP, with size distributions and present elements suggesting they were harvested by mass capture and consumed with little preparation. Lastly, if the unilaterally barbed bone rod at the Lind Coulee site in Washington and the dated bone rod from Pyramid Lake (Nevada) (Dansie and Jerrems 2005) are fishing-related (Daugherty 1956; Irwin and Moody 1978), then there may be a growing corpus of evidence indicating fish and fishing technology were important to WST groups.

The earliest evidence for plant consumption in temperate North America comes from Paisley Caves (Feature 2/6-4; dated to $11,005 \pm 30$ ^{14}C BP and $11,055 \pm 35$ ^{14}C BP) and Shawnee Minisink (Feature 12; dating between $11,020 \pm 30$ ^{14}C BP and $10,820 \pm 50$ ^{14}C BP). The earliest directly dated feature analyzed for plant remains at Bonneville Estates (F3.15; $10,760 \pm 70$ ^{14}C BP and $10,800 \pm 60$ ^{14}C BP) contained five charred seeds, whereas hearths dating to the mid-Younger Dryas (e.g., F4.15 dated to $10,650 \pm 45$ and F4.14 dated to $10,540 \pm 40$ ^{14}C BP) contain higher amounts and a more diverse set of charred plant remains (Graf 2007; Rhode and Louderback 2007; T. Goebel, personal communication 2021). Archaeobotanical data from Dust Cave, Wishbone, and other features from Paisley Caves and Bonneville Estates reflect continued plant use throughout the mid- to late-Younger Dryas. Our research at Connley Caves

contributes a new location where people consumed plants between ~12,000 and 11,600 cal BP and adds additional taxa to the known Younger Dryas food economy.

Archaeobotanical assemblages from some of the oldest preserved hearths in North America suggest that plants have always been a part of people's diets; however, the range and intensity of gathering practices varied regionally and diachronically. Overall, the subsistence record associated with early WST tool technology, particularly Haskett projectile points, includes more diverse plant taxa than found in association with contemporaneous technocomplexes like Clovis, Folsom, Vail-Debert, Bull Brook, and Dalton, which are dominated by a few taxa of wild nut mast and fruits (Gingerich 2011; Gingerich and Kitchel 2015; Haynes and Hutson 2013; Hollenbach 2007; Walker et al. 2001). The debate continues about whether these differences were driven by variability in regional resource availability, taphonomy, recovery strategies, cultural preferences, or other factors. Most likely it is a combination of causes, which require scrutiny, review, and quantification on a continental scale. To some researchers, the archaeobotanical record east of the Rocky Mountains indicates that groups opportunistically foraged low-cost, high-return plant foods—a pattern consistent with hunting-focused lifeways (Gingerich 2011; Gingerich and Kitchel 2015), though botanical remains from Dust Cave suggest that foraging may have been more purposeful after Clovis-times (Hollenbach 2007). Dietary data from Paisley Caves, Bonneville Estates Rockshelter, Wishbone, and now Connley Caves indicate that intentional plant foraging was part of the larger settlement-subsistence strategy for some WST groups by at least the Younger Dryas. Explaining and predicting the incorporation of diverse plant foods may require consideration of nutritional needs beyond caloric gains.

1.10.3. Implications for Settlement-Subsistence Models Based on Caloric Optimization

Anthropologists have long been interested in forager resource-acquisition decisions, and this topic has a lively history in North American Pleistocene archaeology (Grayson and Meltzer 2003, 2015; Grayson et al. 2021; Haynes and Hutson 2013; Surovell and Waguespack 2009; Waguespack and Surovell 2003; Wolfe and Broughton 2020). Most discourse and foraging models related to the Pleistocene archaeological record have focused on hunting. Over the past half century, human behavioral ecology (HBE) has been a popular and productive theoretical framework for explaining past human behavior (Bettinger and Baumhoff 1982; Bird and O'Connell 2006; Coddling and Bird 2015; Kelly 2013; O'Connell et al. 1982; Rhode 1999; Simms 1987; Zeanah and Simms 1999). HBE focuses on applying evolutionary theory and models of optimization to understand human behavior within ecological contexts (Winterhalder and Smith 2000). Dietary optimization models typically use energetic returns as currency; cost/benefit relationships are viewed in terms of time/calories. Though testing these models is beyond the scope of this paper, botanical data from Connley Caves and other WST sites raise questions regarding the ability of caloric optimization to explain some foraging choices. We explore those issues here.

O'Connell and colleagues (1982) were early advocates of the HBE approach in the Great Basin and were optimistic that with refined ecological data such models could be used to understand not only *what* happened in the past but also explain *why* it happened. Using a Diet Breadth Model, they proposed that humans should have bypassed most low-ranked plant resources such as small seeds during the PHT due to the abundance of artiodactyl populations. Simms (1987) agreed that based on energetic return rates, seeds should be ignored, but he also observed that such a prediction did not match regional ethnographic records. Pinson (1999)

argued that risk-adverse foragers of the late Pleistocene positioned their camps in lowland ecotonal settings where lower-ranked (i.e., small game) but predictable resources could be acquired from multiple habitats. More recently, Elston and colleagues developed a comprehensive HBE-grounded model specifically for settlement-subsistence during the PHT (Elston and Zeanah 2002; Elston et al. 1995; Elston et al. 2014). Integrating models of optimal foraging (Charnov 1976; Kaplan and Hill 1992; MacArthur and Pianka 1966) and sexual division of labor (Bird et al. 2001; Coddling et al. 2011; Hawkes 1990, 1991; O'Connell et al. 1988), they proposed groups situated their residential camps near wetlands so that women could supplement diets with small game and riparian resources while men pursued large game. They contended that the greater prevalence and productivity of wetlands during the PHT reduced the cost of travel between patches, making it more energetically efficient for groups to move to a new patch when high-ranked resources (e.g., artiodactyls) were depleted, rather than broadening their diets to include low-ranked resources. These HBE-based models have proven very useful for generating testable expectations, but their proponents have often asserted that plant resources rarely entered the diet or refrained from making specific predictions about which plant items would be selected and when. While there is general agreement that Great Basin groups were never strictly big-game hunting specialists, most researchers contend that foraging goals still should have focused on high-return resources, which would have been more abundant during the late Pleistocene.

Another common narrative in Great Basin archaeology is that plants, and small seeds specifically, did not become a significant part of the diet until the Early Holocene (Beck and Jones 1997; Jennings 1957; Fowler 1986; O'Connell et al. 1982; Rhode et al. 2006; Willig and Aikens 1988). This idea is mainly due to the dearth of groundstone technology and

archaeobotanical remains from late Pleistocene sites. The fact that when circumstances (i.e., adequate preservation and sampling methods) allow, we often find evidence of plant use prior to the widespread appearance of groundstone tools suggests plant resources were crucial to the diets of foraging groups long before evidence of specialized intensification. Furthermore, recent analysis of Early and Middle Holocene artifacts at Hogup Cave in Utah found that milling stones were associated with starch granules from geophytes, whereas basketry yielded starches from small-seeded plant taxa (Herzog and Lawlor 2016). That study highlights the danger of relying on milling stones as a proxy for seed processing.

Some researchers explain selection of low-ranked resources, especially seeds, on the basis of their storability (Simms 1985; Testart et al. 1982), and this risk-reduction strategy is evident in the Fort Rock Basin by the Middle Holocene (Jenkins 2004; Prouty 2004). Clear evidence of plant-food storage, however, has yet to be discovered in the late Pleistocene record (Smith and Barker 2017). Storability is also unable to account for the use of highly perishable foods such as leafy greens. Therefore, neither energetic maximization nor storability/risk aversion seems to explain certain foraging choices apparently made by some Paleoindian groups. Why then, despite comprising the lowest-ranked resource class in terms of caloric return rates (Simms 1985), do small seeds recur in Paleoindian cultural contexts in the Great Basin?

We propose that people may have consumed plants to acquire essential nutrients needed for human growth and reproduction. Nutritional ecology examines the relationship between essential nutrient intake and human health, recognizing that optimal health requires a suite of micronutrients (e.g., vitamins and minerals) in addition to macronutrients (e.g., carbohydrates, fats, and proteins) (Hockett 2012a; Hockett and Haws 2003; Raubenheimer and Simpson 2016). This means that foragers who consume a diverse, nutrient-rich diet benefit from a better

nutritional framework for growth, reproduction, and, therefore, population increase than groups with narrow diets. Macronutrients must be consumed in greater quantities than micronutrients, but that does not diminish the nutritional importance of the latter. Nutritive deficiencies cause health problems and possibly death: “A lack of vitamin-A in a human diet would leave a person as dead as one who starved to death through chronic energy deficiency” (Hockett 2012a:3).

Nutritional ecology has been effectively applied in the interpretation of the Pleistocene zooarchaeological record of the Great Basin (Hockett 2007), as well as other time periods and regions (Hockett 2012b; Hockett and Haws 2003, 2005), but not to the archaeobotanical record of Paleoindian North America. Kennedy and Smith’s use of nutritional ecology in their interpretation of the Holocene (ca. ~10,000 cal BP to contact) archaeobotanical record at LSP-1 rockshelter (Oregon), however, demonstrates the potential of this approach for understanding early plant use. Drawing from the limited nutritional data available for wild plants, Kennedy and Smith (2016:646) observed that cattail and species of the amaranth and grass families contain a suite of essential nutrients including several vitamins (A, C, K), folate, calcium, phosphorus, and dietary fiber that are difficult to acquire through meat alone. Their analysis reveals correlations between nutritional diversity and population growth consistent with the predictions of nutritional ecology and suggests that caloric concerns were not the exclusive impetus behind foraging choices (Kennedy and Smith 2016:647).

Our initial comparison of available nutritional data (Phillips et al. 2014; USDA 2019) for taxa of or similar to dietary constituents recovered from Connley Caves and other Paleoindian sites shows that, overall, plant foods are the best sources for carbohydrates, folate, magnesium, Vitamin A RAE, Vitamin C, potassium, calcium, and manganese (Table 2.4) (also see discussions in Mailer and Hale 2013; Phillips et al. 2014). Each of these nutrients is vital for a

properly functioning human body and its repair, growth, and reproduction. Magnesium and folate, for example, are essential during pregnancy to support embryonic development, oocyte maturation, protein synthesis, and more; deficiencies in these and other micronutrients are linked to numerous birth complications (Fall et al. 2003; George et al. 2002; Laires et al. 2004; Ramakrishnan et al. 1999; Scholl and Johnson 2000). Vitamin A is needed for bone and tissue development (Brown and Noelle 2015), Vitamin C facilitates immunological and cardiovascular functions (Chambial et al. 2013), and potassium works as an electrolyte to regulate fluid balance, nerve signals, and muscle contractions (He and MacGregor 2008). Inclusions of plant foods rich in essential vitamins and minerals increases nutritional diversity and contributes to overall health and reproductive success. This initial comparison is provocative, but nutritional data for the majority of Paleoindian plant foods does not exist, and studies show that nutritional data for similar conventional foods are not appropriate substitutes for that of traditionally gathered wild plants, as the latter may be higher in certain healthful nutrients (Burns Kraft et al. 2008; Phillips et al. 2014). To fully understand the nutritional benefits of these and other Great Basin plant foods and to model Paleoindian plant use, more nutritional data are needed.

Table 2.4. Comparison of macro- and micronutrients of traditionally foraged plant and animal taxa.

Concentration Per 100g	Rabbit	Bison	Elk	Grouse	Trout	Beaked Hazelnuts	Choke-cherry	Rose Hips	Amaranth Grain	Prairie Turnups	Cattail Shoots	Lambsquarters Greens
Energy (kcal)	114	146	111	112	119	628	156	162	102	130	25	43
Protein (g)	21.79	20.23	22.95	25.94	20.48	14.89	2.89	1.6	3.8	2.62	1.18	4.2
Fat (g)	2.32	7.21	1.45	0.88	3.46	52.99	0.98	0.34	1.58	0.36	0	0.8
Carbohydrate (g)	0	0.05	0	0	0	22.98	33.88	38.22	18.69	35.67	5.14	7.3
Dietary fiber (g)	0	0	0	0	0	9.8	17	24.1	2.1	8	4.5	4
Calcium (mg)	12	11	4	5	67	441	40	169	47	130	54	309
Iron (mg)	3.2	2.78	2.76	0.58	0.7	3.12	0.4	1.06	2.1	1.27	0.91	1.2
Magnesium (mg)	29	21	23	32	31	235	21	69	65	63	63	34
Manganese (mg)	-	-	0.012	0.016	0.158	7.6	0.417	1.02	0.854	0.266	0.76	0.782
Potassium (mg)	378	328	312	311	481	738	309	429	135	156	309	452
Vitamin C (mg)	0	0	0	0	2.4	-	0.7	426	-	5.5	0.7	80
Riboflavin (mg)	0.06	0.246	-	0.28	0.105	0.16	0.058	0.166	0.022	0.09	0.025	0.44
Niacin (mg)	0	5.322	-	11.6	5.384	3.19	0.6772	1.3	0.235	1.071	0.44	1.2
Vitamin B-6 (mg)	0	0.383	-	1.275	0.406	0.55	0.193	0.076	0.113	0.47	0.123	0.274
Folate, DFE (ug)	0	12	-	-	12	-	10	3	22	10	0	30
Vitamin A, RAE (ug)	0	0	0	6	19	-	2	217	-	-	1	580
Vitamin E (mg)	0	0.19	-	0.73	-	-	0.75	5.84	0.19	-	0	0
Vitamin K (ug)	0	1.2	-	-	-	-	29.3	25.9	-	0	22.8	0

Note: Nutritional data are from the USDA National Nutrient Database for Standard Reference 28 (USDA 2019) and are given for raw food items, except for Amaranth grain which is cooked.

The increasing appearance of diverse and seemingly low-ranked resources in the emerging Paleoindian plant food economy suggest that we need to explore variables outside of caloric return to explain some aspects of early foraging behavior. At Connley Caves, the cooccurrence of charred plant remains with a lithic toolkit including specialized projectile technology may be explained by a similar division in labor to that proposed by Elston and colleagues (2014). The difference may be that instead of directly provisioning men's hunting activities, women's foraging diversified the diet, providing more essential nutrients and an overall better nutritional framework for growth and reproduction than that achieved through a narrower diet.

1.11. Conclusions

This project has produced one of the most robust archaeobotanical assemblages in the late Pleistocene and earliest Holocene record of North America, revealing new aspects of foraging behavior at Connley Caves and patterns in Paleoindian subsistence more broadly. We offer the following conclusions regarding the archaeobotanical assemblages from Connley Cave 5:

1. Analysis of five combustion features shows that humans recurrently visited Connley Caves during the Younger Dryas and earliest Holocene (ca. ~12,500 to ~10,200 cal BP). During certain visits, people foraged and consumed numerous plants from multiple habitats, including a variety of seeds with some starchy and fruity tissue. Groups foraged for plants during the late summer and early fall, gathering a diverse array of dryland taxa and narrow range of wetland plants. Fishing and sewing are also indicated by some of the features' contents.

2. The traditional narrative of Connley Caves as an important locality for marsh-tethered foragers during the late Pleistocene is partially supported by our analysis. Environmental indicators (e.g., wetland plant taxa and fish) suggest Paulina Marsh was established and productive in the PHT; however, marsh plants do not appear to have been the focus of food foraging activities, with the exception of cattail, rush, and spikerush seeds in features 2 and 4. Analysis of the faunal assemblages, as well as the cultural components below and above the features in this study, are needed to complement the findings presented here and to compare intensity of site use and the relative importance of plant-food resources through time.
3. When placed into the broader dietary record from late Pleistocene sites in temperate North America, Connley Caves reaffirm and expand the diversity of plant resources in the known Paleoindian food economy. These data support the proposal that WST groups in the Intermountain West had broad-based diets that incorporated resources from a variety of ecological habitats.
4. The continued appearance of seemingly low-ranked plant resources in WST sites seems to deviate from expectations derived from calorie-based optimization models. Though testing such models is beyond the scope of this paper, our findings suggest that variables other than caloric returns probably drove some foraging choices, not only during the Holocene but also in the late Pleistocene. Applying a nutritional ecology perspective in future research may help explain foraging behavior.

Archaeobotany is essential for understanding past lifeways yet continues to be underrepresented in Paleoindian research. Human-plant relationships are at the heart of questions about the peopling and settling-in process of the Americas. Though few, research has shown that

plant remains can be recovered from a variety of late Pleistocene contexts, including rockshelter and open-air sites, and stand to reveal aspects of regional adaptations, seasonal mobility, foraging range, labor division, human health, and more. With concerted efforts to recover more micro- and macro-botanical remains and to integrate those data with other subsistence and environmental proxies, we will gain a better understanding of the people and resources that have long been underrepresented in Paleoindian research.

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CHAPTER III

MIDDLE HOLOCENE MENUS: DIETARY RECONSTRUCTION FROM COPROLITES

AT THE CONNLEY CAVES, OREGON, USA*

The Connley Caves feature prominently in our understanding of human occupation and paleoecology of the northern Great Basin. Situated in a hillside overlooking the most productive marsh in the Fort Rock Basin of central Oregon (Figure 3.1), this string of rockshelters was intermittently inhabited by humans for over 12,000 years (Beck et al. 2004; Bedwell 1970; Jenkins et al. 2017). Coprolites (paleofeces) dating between ~5700 and 3200 calendar years before present (cal BP) are preserved in large quantities at the mouth of Cave 5. As one of the most direct sources of unambiguous dietary information (Bryant 1974a; Heizer and Napton 1969; Reinhard and Bryant 1992), these coprolites provide a unique view of food economies, foraging choices, and health of cave inhabitants throughout two millennia.

Evidence of settlement-subsistence patterns during the middle to late Holocene transition in the northern Great Basin show a trend toward increased sedentism as populations “mapped on” to dense patches of lowland resources (Jenkins 1994). Coprolites presented here fall within the Bergen Period (6000 to 3000 cal BP), characterized by decreased mobility, population growth, food caching, and larger groundstone assemblages (Aikens et al. 2011). There is a significant decline in the archaeological record of Great Basin cave and rockshelter sites during the middle Holocene (Aikens 1982; Connolly and Barker 2004; Ollivier et al. 2017).

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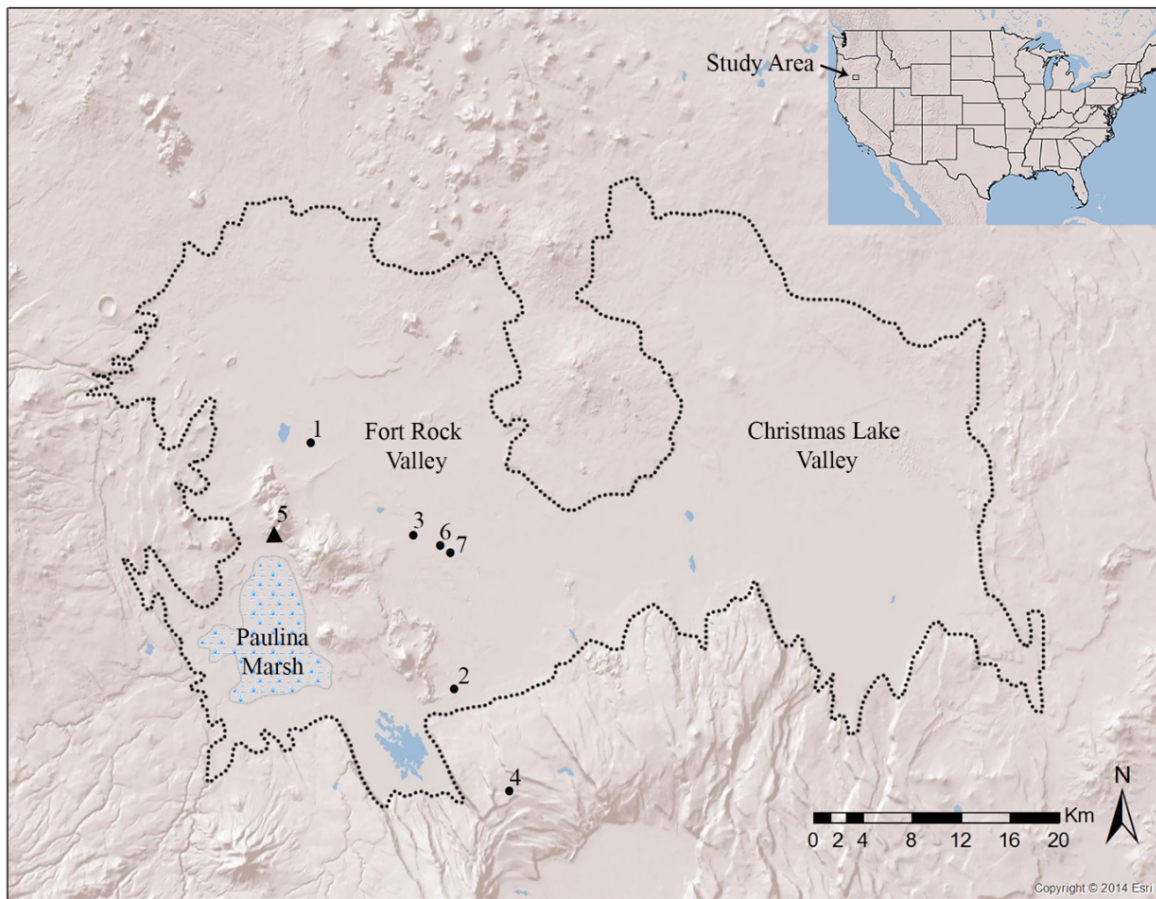


Figure 3.1. Map showing location of the Connley Caves and other sites discussed in the text: 1) Bergen; 2) Big M; 3) Bowling Dune; 4) Boulder Village; 5) Connley Caves; 6) DJ Ranch; 7) Locality III.

This “gap” is particularly evident in the textile record (Connolly and Barker 2004; Ollivier 2016) and likely reflects a change in rockshelter use (Ollivier et al. 2017) and/or population density (Louderback et al. 2011). Due to the paucity of archaeological records from rockshelters during this time, our current understanding of the Bergen Period plant food economy is based on data from open-air sites with archaeobotanical records limited to carbonized plant remains. Coprolites preserved at the Connley Caves provide an opportunity to gain a more holistic perspective on meal constituents and the role of rockshelters during the Bergen Period. Specifically, this study investigates diachronic trends in: 1) dietary diversity and food staples; 2) importance of wetland

versus dryland resources; 3) season of habitation; 4) food preparation practices; and 5) instances of intestinal parasites.

1.13. Environmental and Archaeological Context

1.13.1. Environmental Setting

The Connley Caves site is composed of eight rockshelters eroded into the Connley Hills by wave action from pluvial Fort Rock Lake, which receded from the caves sometime prior to 13,000 cal BP (Friedel 1994; Jenkins et al. 2017). Its position in a transition zone between the valley floor and uplands facilitates access to a variety of ecological habitats. All of the four major biotic communities of the Fort Rock Basin are available nearby including dry/lowland, wet/lowland, upland, and lithosol communities (Housley 1994). The modern landscape surrounding the caves is characterized by widely spaced juniper (*Juniperus*) trees with a sparse understory dominated by sagebrush (*Artemisia*), rabbitbrush (*Chrysothamnus*), and grasses (Poaceae). The Connley Hills support a wide range of important subsistence resources such as currants (*Ribes*), Indian rice grass (*Oryzopsis hymenoides*), sego lily (*Calochortus*), serviceberry (*Amelanchier*), geophytes, and various types of amaranths (Amaranthaceae). Less than 2 km to the south is Paulina Marsh, a large wetland (~82 km²) at the head of a drainage system that feeds neighboring sub-basins during particularly wet periods (Benjamin 1994). As the only recipient of perennial stream flow in the basin, Paulina Marsh is the most extensive and productive wetland in the region (Jenkins and Aikens 1994). Marshland biota such as cattail (*Typha*), willow (*Salix*), bulrush (*Scirpus*), fish, and waterfowl made Paulina Marsh an important location for human foragers for millennia (Bedwell 1973; Grayson 1979; Jenkins and Aikens 1994).

The middle Holocene encompasses some of the driest and wettest periods in Great Basin prehistory. Prolonged drought conditions between ~7800 and 6000 cal BP caused most marshes

and some lakes to dry completely (Aikens et al. 2011). Sand dune deposits (Dugas 1998; Mehringer and Wigand 1986; Mehringer and Cannon 1994), shifts in pollen assemblages (Kelso 1971; Wigand and Mehringer 1985; Wigand 1987), and interruptions in woodrat midden records (Wigand and Nowak 1992; Jennings and Elliott-Fisk 1993) indicate extreme aridity in the northern Great Basin during this time. Ameliorating climatic conditions starting around 6000 cal BP prompted a resurgence of Great Basin lakes and wetlands (Wigand and Rhode 2002). The general transition to a wetter and cooler climate regime between ~6000 and 3000 cal BP bolstered the productivity of lowland marsh and lacustrine habitats (Aikens and Jenkins 1994; Aikens et al. 2011; Minckley et al. 2004; Sampson 1985). Even as drought conditions subsided, alternating wet/warm, cool/dry cycles continued for several millennia (Mehringer and Wigand 1986; Wigand 1987; Wigand and Rhode 2002). Climatic oscillations became more rapid toward the late Holocene (after ~3000 cal BP), as reflected in the vegetation shifts at Diamond Pond (Wigand 1987). These climatic shifts affected the distribution, productivity, and availability of plant and animal resources, which in turn influenced foraging behavior.

1.13.2. Regional Context and Cultural Chronology

Great Basin archaeologists hypothesize that cultural changes are closely tied to environmental shifts (Elston 1982; Grayson 2011; Jenkins 1994). Following this framework, a cultural chronology was developed for the northern Great Basin based primarily on climatic shifts and settlement trends (Jenkins et al. 2004). The middle and late Holocene is divided into three cultural phases that include the Lunette Lake (9000 to 6000 cal BP), Bergen (6000 to 3000 cal BP), and Boulder Village (3000 cal BP to historic) periods. The Lunette Lake Period is characterized by extreme aridity and an archaeological record limited to foraging camps situated on dunes near seasonally active ponds or margins of permanent lakes (Aikens et al. 2011;

Jenkins 2004). The Bergen Period is defined by marsh resurgence, increased sedentism, population growth, appearance of permanent lowland villages, pervasive caching behavior, and increased number of groundstone artifacts. Upturns in the number and diversity of trade items and artistic goods signal increased social complexity (Jenkins et al. 2004). The Bergen Period ends ~3000 cal BP, roughly coincident with intense regional drought and accelerating climatic oscillations (Wigand 1987). Evidence of human occupation in the Fort Rock Basin is more ephemeral between ~3000 and 2000 cal BP as villages were moved closer to root caches in the hills. Large seasonal habitation sites positioned at the base of the foothills and in the uplands near root-collecting grounds appear around 2000 cal BP (Byram 1994; Jenkins and Brashear 1994; Prouty 1994).

The relationship between climatic shifts and settlement-subsistence patterns during the middle to late Holocene transition (ca. 4000 to 3000 cal BP) might be explained by Jenkins' cultural-ecological model for Fort Rock Basin land use (Jenkins 1994). This model views changing settlement-subsistence patterns as human adaptive responses to fluctuating lowland-wetland resources. The extremely productive yet inconsistent qualities of wetland resources were contrasted with the stability of upland root productivity. Focus on the latter intensified when resources were less predictable, as demonstrated by the changing locations and nature of archaeological sites through time. Intensive drought conditions prompted population dispersal to uplands or neighboring basins, while wet periods triggered population surges (Jenkins 1994). During the period of increased moisture ca. ~5000 to 3000 cal BP, human populations "mapped on" to stable and storable lowland resources. Collector-like behavior, including intensive processing and long-term storage of lowland resources, is attributed to population pressure. Off-site caches are interpreted as risk reduction strategies to protect against raids during periods of

site vacancy, suggesting that some degree of mobility persisted during this period of increased sedentism (Jenkins 2004). Upland resource exploitation intensified ca. 4000 cal BP (Brashear 1994; Byram 1994), and by 3000 cal BP population pressure coupled with decreased climatic stability caused populations to shift their residential patterns. Long occupied permanent hamlets and villages situated in valley bottom marshes were abandoned as a two-season residential pattern developed to include upland villages. Groups positioned their fall/winter villages in ecotonal settings between wetlands and upland root grounds, and relocated to their upland villages in the early spring to harvest and cache geophytes (Jenkins et al. 2004). This two-village settlement pattern is best documented beginning ~2000 to 1500 cal BP and persists into the historic period (Brashear 1994; Byram 1994; Jenkins and Brashear 1994; Jenkins 1994b). This model provides a good framework for examining and interpreting subsistence evidence from the Connley Caves.

1.14. Site Background

The Connley Caves first gained recognition following excavations by Stephen Bedwell in the late 1960s when radiocarbon ages in excess of ~13,000 cal BP were obtained in purported association with flaked-stone tools (Bedwell 1970; Bedwell 1973; Beck et al. 2004). Interpretations drawn from Bedwell's early work, however, have been considered tenuous due to imprecise excavation methods and provenience data (Grayson 1979; Jenkins et al. 2002). To rectify this, the University of Oregon Archaeology Field School recently completed its seventh season of excavation (2000, 2001, 2014 to 2018) at the caves, with the goal of refining chronological and ecological records (Jenkins et al. 2002, 2017). Though Bedwell used a backhoe to remove much of the sediment overlying the Mazama tephra layer (ca. 7770 cal BP) inside of caves 4 and 5, Holocene deposits were found intact in a shallow alcove located between

the caves. The alcove is located at the eastern edge of the cave 5 entrance and is considered part of the cave 5 excavation block.

The Cave 5 alcove contains textiles, lithic artifacts, and over 100 coprolites spanning the middle and late Holocene (McDonough and Jenkins 2018; McDonough et al. 2018). Coprolites presented in this study all date to the Bergen Period, and were found in Stratum III of excavation units 15, 17, 19, 22, and 22A (Figure 3.2). Stratum III is composed of yellowish brown (10YR 5/6) silt with varying quantities of angular gravel extending from ~50 to 130 cm below the surface (Jenkins et al. 2002). A thin layer of brown silt and colluvium (Stratum IV) underlies Stratum III, separating it from the layer of Mazama tephra dating to ~7770 cal BP (Bacon 1983; Egan et al. 2015). Radiocarbon ages on coprolites and associated artifacts from Stratum III range from ~5700 to 3200 cal BP (Table 3.1) and are in good stratigraphic sequence. An eastward slope in stratigraphy explains the slightly older age of coprolite C6 relative to C11, which is 4 cm lower in elevation. The preponderance of refuse items, such as broken basketry, debitage, and human excrement, suggests use of this area as a trash midden and/or latrine. Other artifacts in this area include bundles of grass, shredded bark, textile fragments, netting, debitage, edge-modified obsidian flakes, and one Elko series projectile point. There is other evidence of middle and late Holocene occupations of the Connley Caves that includes additional Elko series and Northern Side-notched projectile points, groundstone, and directly-dated textiles (Bedwell 1970; Jenkins et al. 2002; Thatcher 2001).

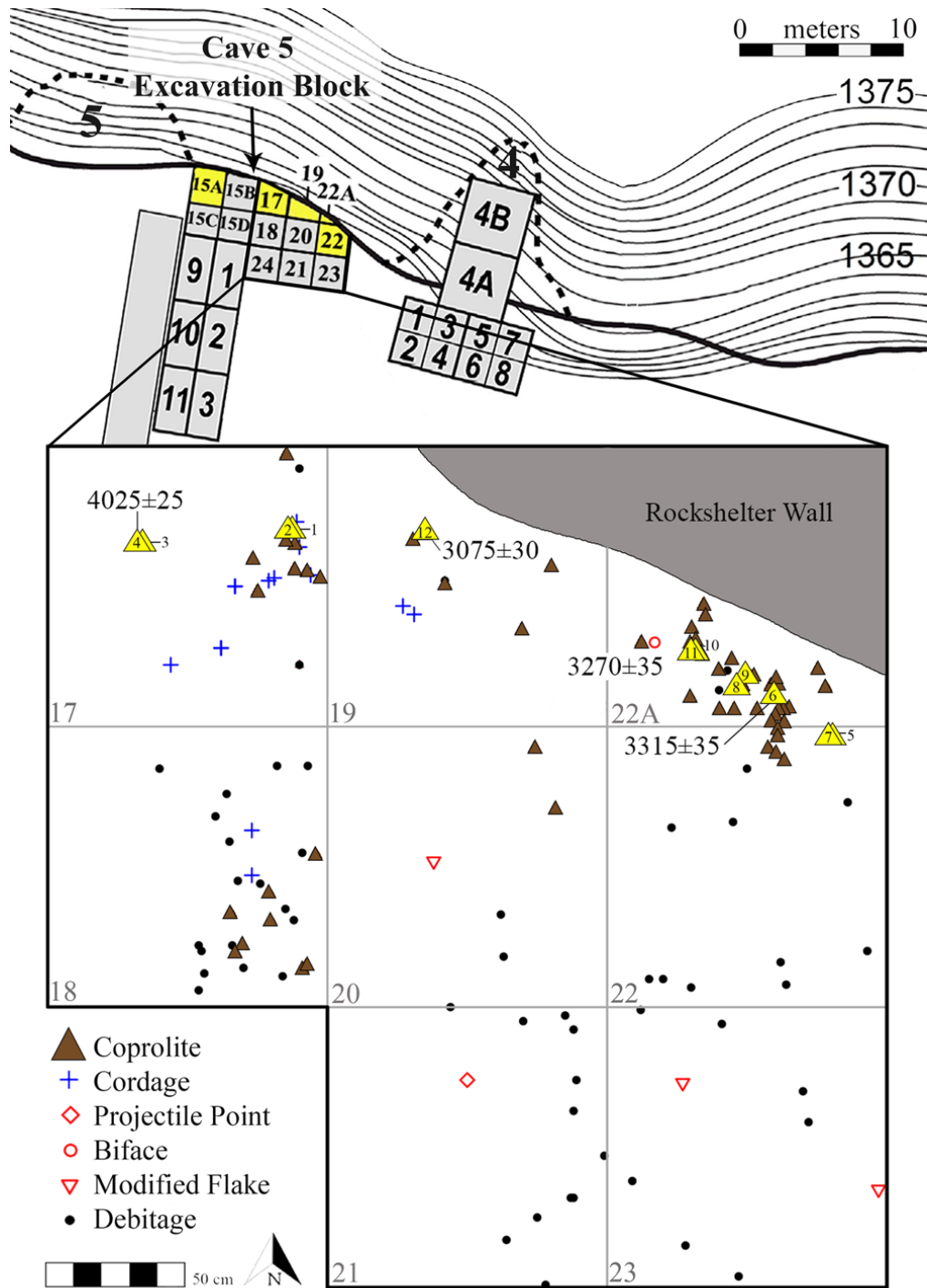


Figure 3.2. Plan view of the Connley Caves with an inlay of artifacts coprolites found in the latrine area between depths of 1357.70 and 1358.15 meters above sea level (provenience data not available for Unit 15 Series).

1.15. Materials and Methods

This study examines macrobotanical, faunal, and microfossil data from 16 coprolites. Four specimens were recovered from unit 15A during the 2001 field season and were analyzed by the Paleoresearch Institute (“Unit 15 Series”: A6, A7, EW1, EW14) (Cummings et al. 2002). Twelve coprolites (“C Series”: C1-C12) were excavated in 2014 and 2015 from units 17, 19, 22, and 22A. The C Series was processed and analyzed at the Texas A&M Palynology Research Laboratory (TAMU PRL) in College Station, Texas. Processing procedures for the C Series coprolites are described in this section. Materials and methods for the Unit 15 Series are reported by Cummings and colleagues (2002). Samples are linked to a temporal scale based on direct radiocarbon ages and stratigraphic position.

Table 3.1. Radiocarbon ages from coprolites and associated materials for the middle to late Holocene transition at Connley Caves^{a,b}.

Catalog Number	Coprolite Number	Lab Number	Unit	¹⁴ C date and error	2σ cal yr BP range ^a	Material Dated	Primary Reference
2380-CC-5/19-5-1-233b	C12	D-AMS23362	19	3075±30	3365-3210	Coprolite (netting)	Current study
2380-CC-5/22A-12-7	C11	D-AMS23360	22A	3270±35	3575-3405	Coprolite (<i>Scirpus</i>)	Current study
2380-CC-5/22A-11-9	C6	D-AMS23359	22A	3315±35	3630-3460	Coprolite (<i>Juniperus</i>)	Current study
Not assigned		Gak-2133 ^b	5A	3330±110	3860-3350	Charcoal	Bedwell 1970
2202-CC-5/17-24-2109		18P-0858	17	3790±30	4285-4085	Basketry (Catlow twine)	Current study
1265-CC-15A-6-4	A6	Beta-170204	15A	3920±80	4570-4095	Coprolite	Beck et al. 2004
1265-CC-15A-7-4	A7	Beta-170205	15A	3970±150	4840-3995	Coprolite	Beck et al. 2004
2202-CC-17-17-1433	C4	D-AMS026711	17	4025±25	4570-4425	Coprolite (<i>Artemisia</i>)	Current study
1265-15D-12-15		Beta-164960	15D	4240±50	4950-4585	Basketry	Beck et al. 2004
Not assigned		Gak-2134 ^b	5A	4320±100	5290-4590	Charcoal	Bedwell 1970
1265-CC-15A-EW-1	EW1	Beta-170207	15A	4460±90	5315-4860	Coprolite	Beck et al. 2004
1265-CC-15C-11-5		Beta-164959	15C	4520±40	5310-5045	Netting	Beck et al. 2004
1265-CC-15D-9-2		Beta-164958	15D	4590±50	5465-5050	Basketry	Beck et al. 2004
1265-CC-5/15D-12-15		18P-0854	15D	4660±30	5470-5315	Basketry (open twined mat)	Current study
1265-CC-15EW-14	EW14	Beta-170206	15A	4930±70	5890-5490	Coprolite	Beck et al. 2004

^aAll radiocarbon ages calibrated using OxCal 4.2 online program (Ramsey 2009) with IntCal 13 curve (Reimer et al. 2013).

^bDates run by Gakushian Laboratory have elicited concern from several researchers (e.g., Banks and Wigand (2005); Blakeslee 1994; Maschner 2004) due to discrepancies with radiocarbon ages on associated materials run by separate labs.

1.15.1. Laboratory Procedures and Analysis

Coprolites were weighed, photographed, and described following Jouy-Avatin et al. (2003) prior to subsampling. Each sample was brushed to remove the external layer of dust and cut crosswise with a sterile razor. One half was curated and the other transferred to a 100 ml sterile sample container where it was left to rehydrate in a 0.5% trisodium phosphate (Na_3PO_4) solution for a minimum of 48 hours (Callen and Cameron 1960). Color and odor of the solution was noted upon complete disaggregation. All samples but C1 turned opaque brown to black in color with no observable scatological odor. C1 turned a light yellow-brown color. Upon complete disaggregation each sample received two tablets containing *Lycopodium clavatum* C. *linneaeus* spores (C1-C4 batch #177745; C5-C12 batch #48321; $18,484 \pm 829$ per tablet) dissolved in 2 ml solution of 15% hydrochloric acid (HCl).

Samples were washed through 250 μ mesh into a beaker (Bryant 1974b). An ethanol solution (95%) spray was used at the end of the screening process to break surface tension and disperse trapped microfossils. The coarse fraction ($>250 \mu$) was rinsed with water and kept hydrated under refrigeration for macrobotanical and faunal analysis. The fine fraction ($<250 \mu$) was decanted five times to remove large silicates, concentrated by centrifugation (3,000 rpms for 2 minutes), and homogenized with distilled water via vortex in 15 ml centrifuge tubes. A 5 ml subsample was reserved for parasite analysis prior to chemical processing (Warnock and Reinhard 1992), and the remaining material was processed for pollen.

1.15.1.1. Macrofossils

The coarse fraction was visually inspected under 10x to 60x power with a Nikon SMZ-1B binocular microscope. Samples were kept hydrated while constituents were separated into categories of seed, plant tissue, charcoal, bone, and insect. To prevent clumping and breakage

during the drying process, individual macrobotanical and faunal specimens were transferred to petri dishes and allowed to dry separately. Each seed fragment, including identifiable and unidentifiable fragments, was considered as one seed in the count calculation. Samples were analyzed in their entirety unless the number of seeds exceeded 1000, in which case a 5-ml homogenized subsample was analyzed to determine an estimated frequency. Density values were determined by dividing the raw taxon count by sample weight. Plant macrofossils were compared with reference specimens housed in the TAMU Paleoethnobotany Laboratory, modern comparative seeds provided by the U.S. National Plant Germplasm System, online databases (USDA PLANTS 2017), and identification guides (Bonner 2008; Delorit 1970; Martin and Barkley 1961). Assistance with macrobotanical identification was provided by Jaime Kennedy and Margaret Helzer. Seed types were verified by Kathryn Puseman of Paleoscapes Archaeobotanical Services Team, LCC (Puseman 2018, Appendix B). Classification of faunal remains was aided by Timothy Campbell.

1.15.1.2. Pollen

Pollen extraction began with removal of fine silicates with a 30-minute treatment in 9 ml of hot 48% hydrofluoric acid (HF) followed by three water washes and one glacial acetic acid ($\text{CH}_3\text{CO}_2\text{H}$) wash. Treatment with 15% HCl removed carbonates. Samples were mixed with 8 ml of acetolysis solution (9:1 mixture of acetic anhydride and sulfuric acid), placed in a heating block (80-90 °C), and stirred regularly with a glass rod for 10 minutes to dissolve organic compounds (Erdtman 1960). One $\text{CH}_3\text{CO}_2\text{H}$ wash and two water washes followed. Remaining organic detritus was oxidized with 8 ml of distilled water and two drops of 6% sodium hypochlorite (bleach) stirred vigorously for 30 seconds followed by five water washes. Pollen residue was stained with three drops safranin-O and stored in 2-ml vials with eight drops

glycerin. A minimum of two microscopic slides were prepared per coprolite sample using sterile toothpicks to prevent ‘edge effect’ (Brookes and Thomas 1967) and glass coverslips sealed with clear commercial nail lacquer. Slides were scanned in transects using a binocular compound microscope on 400x power. Pollen identifications were made to the lowest possible taxonomic level using standard identification keys (Kapp 1969; Kapp et al. 2000), the TAMU PRL comparative collection, the PalDat Palynological Database online resource (www.paldat.org), and through consultation with Vaughn Bryant.

A minimum 200 pollen grain count was obtained for each sample (Barkley 1934; Bryant and Hall 1993; Faegri and Iversen 1989). *Lycopodium* spores were counted but not included in the pollen sum. Relative pollen frequencies and pollen concentration values (PCV) were determined for each taxon in each sample. Pollen frequencies were calculated by dividing the sum of pollen grains of a particular taxon by the total number of grains counted in the sample. PCV per gram of coprolite was determined using the following formula (Benninghoff 1962; Maher 1981):

$$\frac{(\# \text{ fossil pollen counted}) (\# \text{ *Lycopodium* spores added})}{(\# \text{ *Lycopodium* spores counted}) (\# \text{ grams of sample})}$$

The purpose of palynological analysis here was to test for the ingestion of economic pollen taxa and to examine seasonal data. The presence of pollen within a coprolite does not necessitate economical association, as pollen can enter the digestive system incidentally through inhalation of ambient pollen and ingestion of contaminated drinking water or food resources (Bryant and Hall 1993; Dean 1993; Reinhard 1993). Additionally, pollen grains travel through the human digestive system at variable rates and can reflect a mixture of multiple meals consumed over a number of days (Kelso 1976; Tennison 2005; Williams-Dean 1978). This study

used five criteria modified from Battillo (2017) to determine economic association: 1) mechanism of pollen distribution (Bryant and Holloway 1983; Reinhard et al. 1991); 2) frequency of pollen taxon within sample (Dean 1993; Reinhard 1993); 3) aggregates of pollen grains of the same taxon suggesting anther ingestion; 4) derivation from the average frequencies for the series (Reinhard et al. 1991); and 5) comparison with macrobotanical assemblage. Pollen data are discussed primarily with reference to frequency because individual taxonomic concentration values were not available for the Unit 15 Series. Raw counts and concentration values are provided in the Supplementary Material (Appendix B).

1.15.1.3. Parasites

Preparation for parasite analysis was modified from the rehydration-homogenization-micro-sieving (RHM) protocol developed by Bouchet et al. (2001). Samples were homogenized via agitation with a glass stirring rod and screened through a series of micro-sieves at 40, 70, and 100 μ , resulting in four size fractions for each sample. The sieved material was concentrated through centrifugation (3,000 rpms for 2 minutes). The same method described for the pollen slides was used to prepare two microscopic slides per size fraction, resulting in eight slides per coprolite sample. Slides were scanned in transects using a binocular compound microscope at 400x power.

1.15.1.4. Statistics

All statistical analyses were conducted with R 3.4.1 (R Core Team 2017) software. Spearman and Pearson correlation coefficients were computed to assess the relationship between coprolite richness (number of taxa per sample) and sample weight. There was no correlation between these variables, suggesting that greater richness is not a consequence of larger sample size. Hierarchical cluster analysis was conducted to examine patterns of co-occurrence among

primary dietary taxa (e.g. Rhode 2003; Riley 2008; Sutton and Reinhard 1995). Cluster analysis is an exploratory statistical technique well suited for coprolite analysis because it treats each sample as an individual entity and does not assume normal data distribution (Riley 2008). Abundances of the top ten taxa were quantified on a five-part ordinal scale following Rhode (2003) and used for input: saltbush (*Atriplex* sp.), cattail (*Typha* sp.), grass (Poaceae), rush (*Juncus*-type), bulrush (*Scirpus*-type), blazingstar (*Mentzelia* sp.), juniper (*Juniperus* sp.), sumac (*Rhus* sp.), fish, and nondiagnostic bone. Following Riley (2008), Ward's method was used as the clustering technique and Squared Euclidean distance as the distance measure. Ward's method is a hierarchical clustering technique that creates compact clusters by minimizing the within-cluster variance as measured by a sum-of-squares index.

1.16. Results

The sixteen coprolite subsamples in this study contain approximately 84,900 seeds, 473 (NISP) bone fragments, plant tissue, pollen, feathers, hair, fish scales, insects, charcoal, parasite eggs, mites, and a wad of netting. The macrobotanical record shows that saltbush, grass, cattail, rush, bulrush, blazingstar, juniper, sumac, wildrye (*Elymus* spp.), knotweed (*Polygonum* sp.), and possibly cherry (*Prunus* sp.), pondweed (*Potamogeton* sp.), and pine (*Pinus* spp.) were consumed. Mammal, fish, and bird use are demonstrated by bones, scales, and feathers. The pollen assemblage suggests economic use of plants in the amaranth (Amaranthaceae), grass, cattail (Typhaceae), wild carrot (Apiaceae), composite (Asteraceae), and lily families (Liliaceae). Unambiguous evidence of parasites is limited to Taeniid eggs in Sample C12 and mites in C4. C12 also contains a wad of netting. Coprolite constituents are quantified within an ordinal scale of abundance (*sensu* Rhode 2003) in Table 3.2.

Table 3.2. Contents of Connley Cave coprolites^{a-d}.

	EW14	EW1	C4	C3	A6	C2	C1	A7	C11	C10	C7	C8	C9	C5	C6	C12
Catalog number	EW14	EW1	C4	C3	A6	C2	C1	A7	C11	C10	C7	C8	C9	C5	C6	C12
Radiocarbon age (¹⁴ C yr BP)	4930 ±70	4460 ±90	4025 ±25		3920 ±80			3770 ±150	3270 ±35						3315 ±35	3075 ±30
Elevation (cm below 1359 masl)	WF ^d	WF ^d	130	130	WF ^d	127	127	WF ^d	120	120	119	118	118	117	116	88
<i>Weiland Seeds</i>	Cattail (<i>Typha sp.</i>) seed ^c	4	5						4	5	5					1
	Rush (<i>Juncus</i> -type) seed ^c					1			4	4						2
	Bulrush (<i>Scirpus</i> -type) seed cf. Pondweed (<i>Potamogeton</i>) seed ^c								2*	2*						
											1					
<i>Dryland Seeds and Fruits</i>	Saltbush (<i>Atriplex sp.</i>) seed	2	4	4	4	2	2		3	4	3	4	3			3
	Saltbush fruit	2	4	3	2	3	3				3	3	2			
	Poaceae seed		4			4			1	1	1	1	2			
	Blazingstar (<i>Mentzelia sp.</i>) seed			2										1		3
	Juniper (<i>Juniperus sp.</i>) seed					2									2	
	Wildrye (<i>Elymus spp.</i>) floret				3											
	Knotweed (<i>Polygonum</i>) seed															1
	Sumac (<i>Rhus sp.</i>) seed ^c	5														
	cf. Sumac seed ^c												2			
	cf. Cherry (<i>Prunus sp.</i>) seed cf. <i>Pinus spp.</i> Seed			1											2	
Unidentified seed (type k)						1							4	2		
<i>Other Vegetal Material</i>	Cattail pollen ^c								1	2					1	1
	Apiaceae pollen ^c															2
	Bulb scale cf. <i>Allium sp.</i> ^c			P	P				P	P				P		
	Plant tissue and fibers		A	A	A	A	P	A	A	A	A	P	A	A	A	A
	Charcoal		P	A	A	P	A	P	A	A	P	A	A	A	P	A
	Sap					A									A	

	EW14	EW1	C4	C3	A6	C2	C1	A7	C11	C10	C7	C8	C9	C5	C6	C12
Catalog number	EW14	EW1	C4	C3	A6	C2	C1	A7	C11	C10	C7	C8	C9	C5	C6	C12
Radiocarbon age (¹⁴ C yr BP)	4930 ±70	4460 ±90	4025 ±25		3920 ±80			3770 ±150	3270 ±35						3315 ±35	3075 ±30
Elevation (cm below 1359 masl)	WF ^d	WF ^d	130	130	WF ^d	127	127	WF ^d	120	120	119	118	118	117	116	88
<i>Faunal Material</i>	Unidentified bone	1	1		3		3	3	2	2	1		2		1	2
	Fish bone (B) or scales (S)						1-S	3-S		1-B				2-B		2-B
	Bird feathers			P												A
	Hair			P		P	A									
	Insect parts	1				4		2				1		1		2
	Scorpion							1								
	Parasite			P												

^aAbundances of macroremains are quantified on a 5-part ordinal scale modified from Rhode (2003): 1 (rare)=<1/g; 2 (present)=1-10/g; 3 (common)=11-100/g; 4 (abundant)=101-1000/g; 5 (dominant)=>1000/g. Plant fiber, charcoal, and sap is marked present (P) if 1-9 fragments/g and abundant (A) if >10 fragments/g.

^bPollen abundances are quantified on a 5-part ordinal scale using pollen frequency: 1=<20%; 2=20-40%; 3=40-60%; 4=60-80%; 5=80-100%.

^cPreviously unrecognized in the archaeobotanical record of the northern Great Basin during the Bergen Period.

^dSome coprolites were recovered from wall fall (WF) in unit 15 and do not have precise provenience data.

*Seeds are charred.

1.16.1. Macrofossils

The coprolites contain at least 15 taxa of seeds from 12 plant families (Figure 3.3). Saltbush seeds are the most ubiquitous (12, 75%), followed by saltbush fruits (9, 56%), grass seeds (7, 44%), cattail seeds (6, 37%), rush seeds (4, 25%), and blazingstar seeds (3, 19%). Unidentified “type k” seeds appear in four samples (25%)(see C12 unidentified in Puseman 2018, Appendix B). Knotweed, juniper, and bulrush seeds each appear in two (12.5%) samples. Knotweed and wildrye seeds are each present in one (6.25%) sample. Samples containing juniper seeds also contain sap (C6 and A6). Cummings and colleagues (2002:10) identified a large amount of sumac seeds in sample EW14 (6.25%). Seed fragments similar to sumac seeds were also found in sample C8 but could not be confirmed due to fragmentation. Seeds resembling cherry, pondweed and pine each appear in one specimen (6.25%) but are also too fragmented to be positively identified. Plant tissue, present in all but two coprolites (EW14 and C1), is abundant in most samples (12; 75%) and present in two (12.5%) samples. Plant tissue with epidermal structure similar to bulb scales of wild onion (*Allium* spp.) appears in five (31%) samples. All but two samples (EW14, C1) contain charcoal. Charred bulrush seeds paired with the presence of abundant charcoal fragments in two samples (C10 and C11) might be the result of parching. Other indications of food preparation include crushed and highly fragmented seeds of saltbush and cattail, possibly due to milling. Some of the blazingstar seeds in specimens C4 and C12 are also crushed, but it is unclear if this is the result of food preparation or digestive processes.

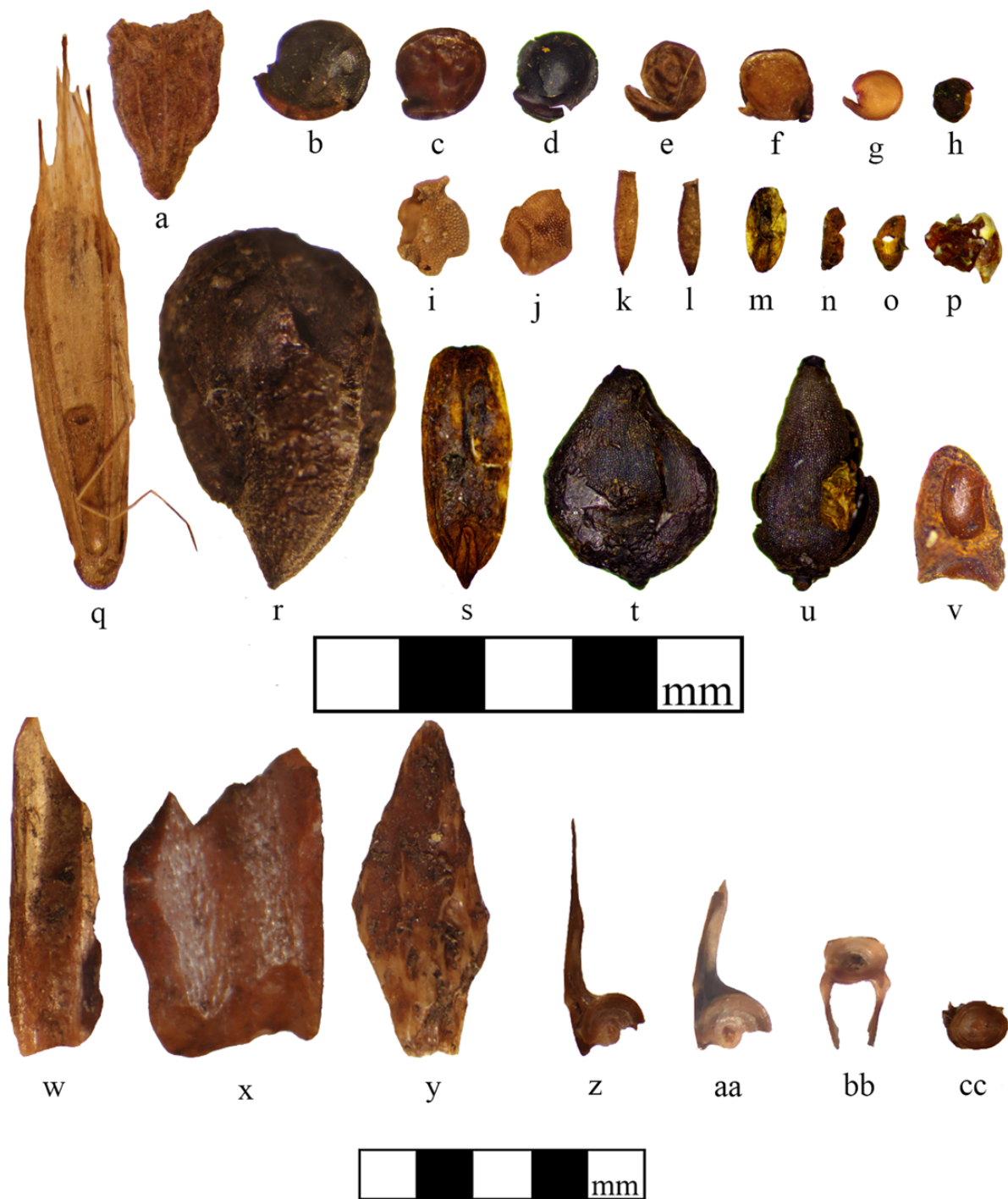


Figure 3.3. Macrobotanical remains found in coprolites: a) *Atriplex* fruit; b-e) *Atriplex* seeds; f-h) Amaranthaceae seeds; i-j) *Mentzelia* sp. seeds; k-l) *Typha* sp. seeds; m) Type K seed; n-o) *Juncus* sp. seeds; p) sap; q) *Elymus* sp. floret; r) *Juniperus* sp. seed; s) Poaceae seed; t-u) *Scirpus*-type seeds; v) cf. *Potamogeton* seed fragments; w-y) nondiagnostic bone; z-cc) fish vertebrae.

All but two coprolites (EW14 and C3) contain evidence of animal consumption. Twelve (75%) coprolites contain bone, of which one fragment is charred (EW1). Fish is represented by diagnostic bone fragments or scales in five (31%) samples, hair or fur is in three (18%), and bird feathers are in two (12.5%). Insect fragments were observed in six samples (37.5%), and a scorpion chela was found in C1 (6%). Many of the bones were highly fragmented and acid-etched from digestion. A full taphonomic analysis of the faunal assemblage is forthcoming.

1.16.2. Microfossils

At least 27 plant taxa are represented in the pollen assemblage. Figure 3.4 displays a pollen diagram for frequencies determined from the C Series, and Figure 3.5 provides examples of pollen taxa discussed in the text. Concentration values range from 22,892 to 210,058 grains per gram, and richness ranges from six to 14 taxa per sample. Pollen from the amaranth, grass, carrot, lily, composite, and cattail families are considered economically associated.

Pollen of the amaranth, grass, and pine families are the most ubiquitous and abundant types in the assemblage. Many of these families contain anemophilous (wind pollinated) taxa that are expected in the local pollen rain; however, high frequencies and pollen-grain clumping in some samples suggests intentional consumption. The frequency of Amaranthaceae pollen is above 40% in six coprolites (C2, C4, C8, EW1, EW14, and A6). The presence of saltbush fruits and seeds in all six of these samples confirms direct consumption. Grass pollen is over 40% in six coprolites, five of which also contain grass seeds (C3, C7, C9, C11, and EW1). These data show that in the Connley Cave coprolites high frequencies (>40%) of amaranth family and grass pollen are usually tied to dietary constituents. The two samples (C1 and A7) containing over 40% pine pollen are characterized by an absence of seeds coupled with large quantities of bone

(>50 NISP) and fish remains. Pine pollen may have been inhaled, imbibed with water, or ingested with food.

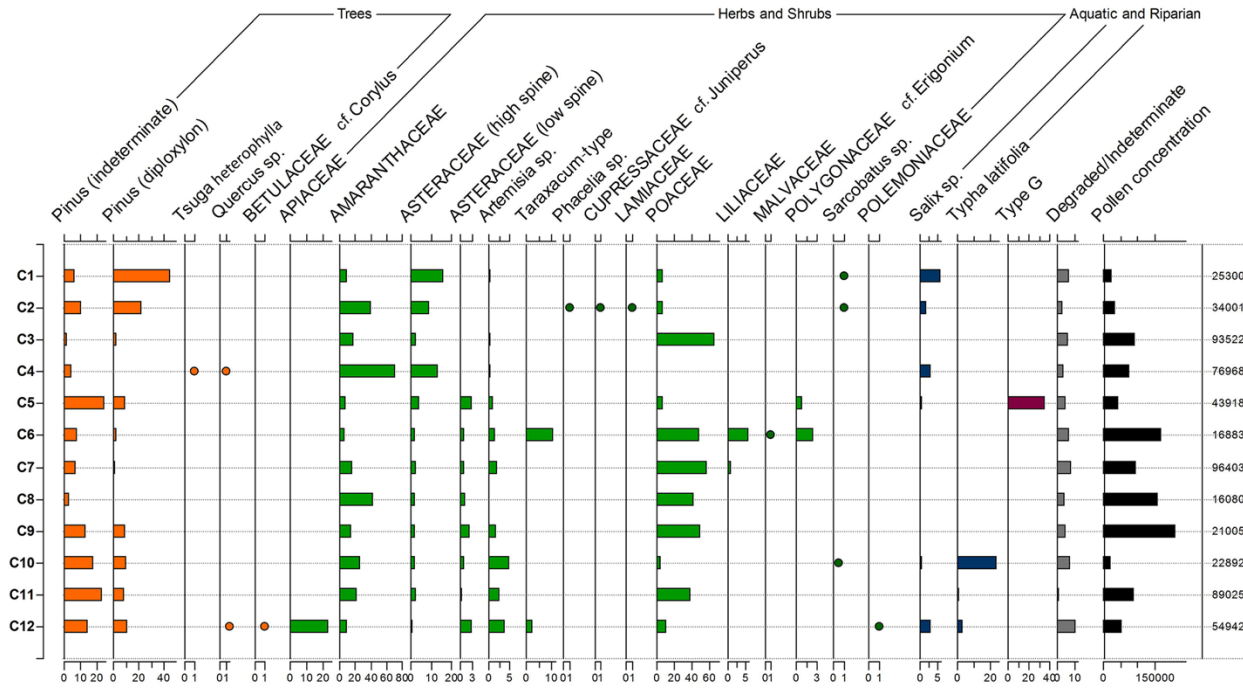


Figure 3.4. Pollen diagram depicting the relative frequency and total pollen concentration values for each coprolite in the C Series.

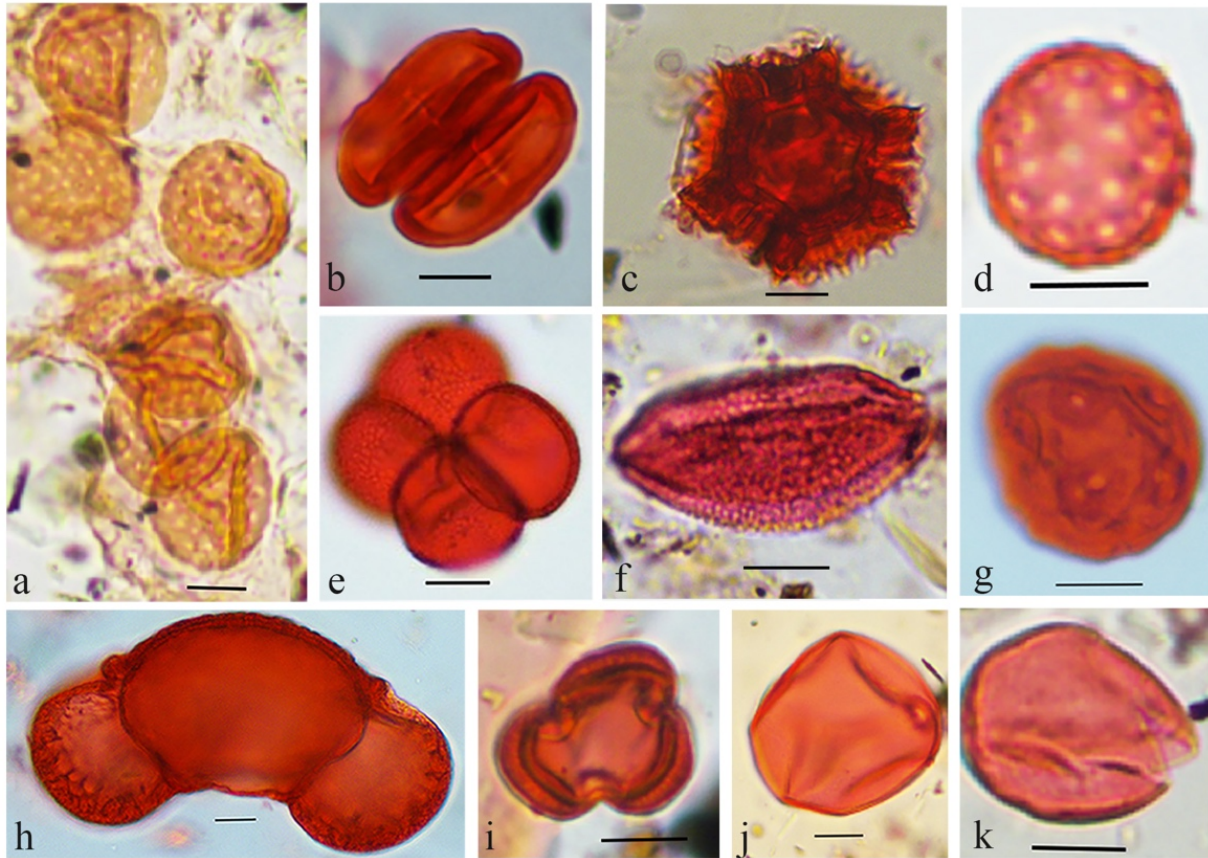


Figure 3.5. Selected pollen grains recovered from coprolites: a) clumped Amaranthaceae; b) clumped Apiaceae; c) *Taraxacum*-type; d) Amaranthaceae; e) *Typha latifolia*; f) Liliaceae; g) *Sarcobatus* sp.; h) *Pinus* sp.; i) *Artemisia* sp.; j) Poaceae; k) *Juniperus* sp.

Less ubiquitous taxa occurring in unusually high frequencies include high-spine composite, carrot family, dandelion-type, lily family, and broadleaf cattail (*Typha latifolia*). Pollen of entomophilous (insect pollinated) plants does not typically travel long distances in large amounts; therefore, high occurrence of such taxa in coprolites indicates economic association (Bryant 1974b; Reinhard and Bryant 1992). Thresholds ranging from 4% (Reinhard et al. 1991) to 10% (Bryant and Williams-Dean 1975) of entomophilous pollen are recommended as signals of intentional consumption. High-spine composite pollen is present in all samples, though rarely exceeding 10% (average ~6%). The presence of this type in excess of 25% coupled

with pollen clumping in coprolite A7 is consistent with direct consumption of plant anthers. These pollen grains compare well with locally available plants such as rabbitbrush (*Chrysothamnus*) and sunflower (*Helianthus*); however, identification beyond the family level was not possible due to the morphological similarity between the pollen of these and other Asteraceae. Anther consumption is also indicated by clumping and high frequency (23%) of carrot family pollen in C12. Coprolite C6 contains 11% dandelion-type and 6% lily family pollen. These insect-pollinated taxa are absent or negligible (>1%) in other samples, and their frequency here suggests direct consumption. The 24% cattail pollen in C10 deviates significantly from the series average for that taxon (2.4%), and evidence of consumption is corroborated by ~11,830 cattail seeds in that coprolite.

1.16.3. Parasites

Parasites were identified in at least two coprolites. Six unequivocal ova belonging to the family Taeniidae (tapeworm) were found in C12. One potential *Ancylostoma* (hookworm) parasite egg and seven *Acari* (mites) were found in C4. The potential hookworm egg in C4 was observed in a slide prepared for pollen analysis (Figure 3.6: d). Poor preservation and lack of additional eggs in the C4 RHM samples prevent positive identification and preclude further discussion at this time.

Six eggs in C12 are morphologically consistent with the family Taeniidae (tapeworm). These spherical ova are non-operculate, 34 μ to 37 μ in length, and exhibit thick brown radially striated embryophore (Figure 3.6: a-c). Distinct hooklets are visible in the oncosphere of several specimens. The estimated number of eggs per gram (EPG) is approximately 1,888; however, the intermittent dispersal of ova within gravid proglottids diminishes the utility of EPG for determining worm burden (Ash et al. 2017). Eggs of the genera *Teaenia* and *Echinococcus* are

morphologically indistinguishable at this life-cycle stage, preventing higher identification.

Sample C4 contained bodies of seven mites. These mites closely resemble a specimen recovered from mummy fecal samples at Lovelock Cave, Nevada (Radovsky 1970). Radovsky identified the Lovelock Cave mite as a tritonymph in the family Acaridae and suggested it was ingested with food or incorporated post-depositionally through coprophilous insects. Additional mummies containing fecal matter with mites are known from Nevada (Pyramid Lake Burial #2, site 26WA525) (Radovsky 1970), the Ozark Mountains (Wakefield and Dellinger 1936), and Peru (Allison et al. 1974). The vast number of mite taxa makes identification difficult and limits the utility of this component to inform on human behavior.

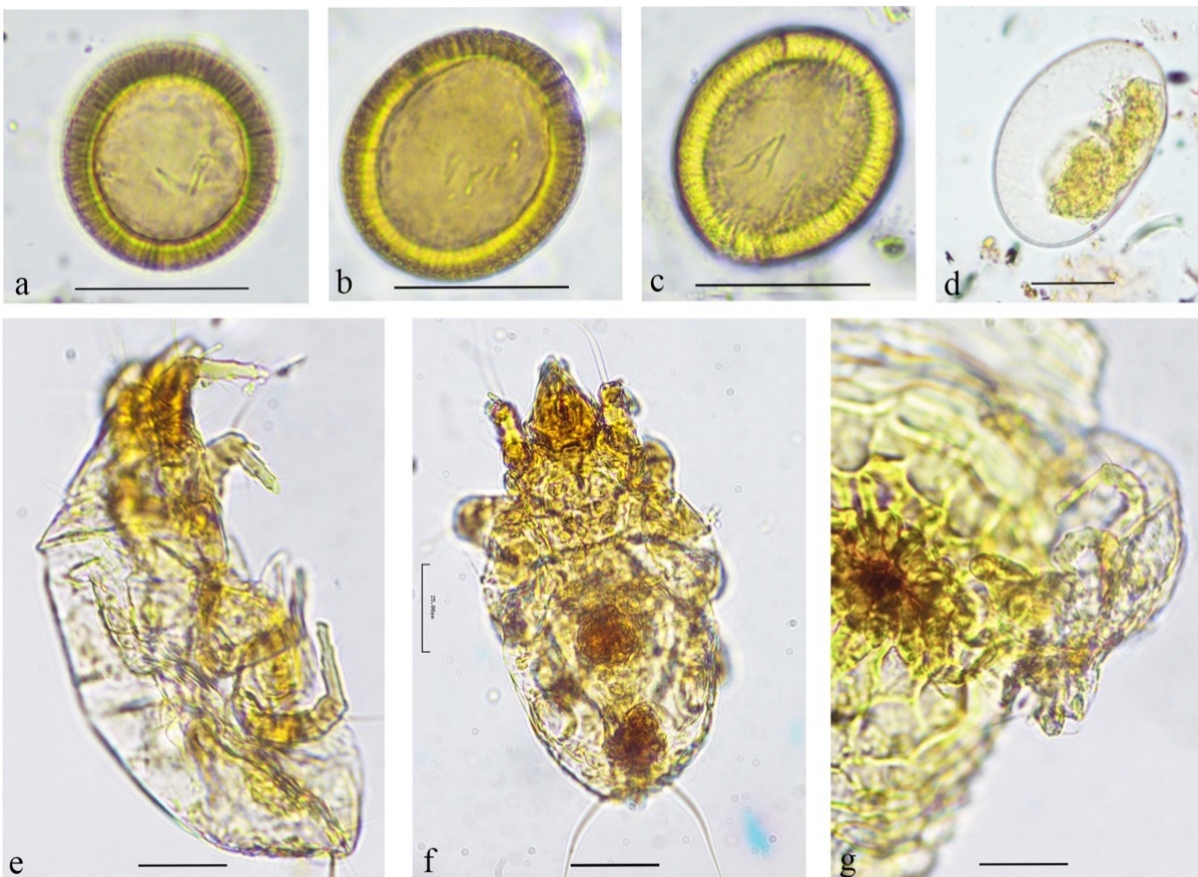


Figure 3.6. Parasites found in coprolites: a-c) Taeniid eggs; d) possible helminth egg; e) mites.

1.16.4. Other Constituents

Coprolite C12 contained a wadded fragment of netting that returned a radiocarbon age of 3075 ± 30 (3365-3210 cal BP; Table 3.1). The inclusion of netting within the coprolite is perplexing but not unique. Evidence of cordage ingestion has been observed in paleofeces from other cave and rockshelter contexts within the Great Basin (Jenna Battillo, personal communication, April 2018; Ted Goebel, personal communication, January 2019). In addition to the netting, coprolite C12 contained six types of economically important seeds (rush, saltbush, blazingstar, cattail, knotweed, and “type k”), fish bones, bird pin feathers, small charcoal fragments, high frequencies of pollen from the carrot and cattail families, plant tissue resembling wild onion, and parasite eggs (Table 3.2).

1.16.5. Assessment of Human Origin

All coprolites are considered very likely to be human in origin, with the exception of C1 and A7, based on assessment of criteria outlined by Reinhard and Bryant (1992). These criteria include archaeological context, sample morphology, color during rehydration, and coprolite contents. The context of the coprolites in a latrine or trash midden suggests but cannot confirm human origin. Examination of fecal morphology of the C Series with reference to the morphometric guide published by Chame (2003) shows that all but one sample (C1) best fit Group IX, which includes various omnivore and primate scats. C1 has a distinct morphology matching cylindrical feces produced by members of the Carnivora Order (Group 1). The color of rehydration solution is also considered a useful method for distinguishing human and non-human feces (Callen and Cameron 1960; Fry 1977; Reinhard 2017). Dark brown to black rehydration colors are associated with human origin (but see Reinhard and Bryant 1992; Wilke and Hall 1975). During rehydration of the C Series, coprolite C1 was the only sample that did not turn the

dark brown/black color typically associated with human origin. Instead, C1 turned a light yellow-brown color. Nearly all coprolites contained a variety of economically important plant taxa, often with evidence of food preparation practices such as milling or, less frequently, toasting. Samples C1 and A7 are the only samples lacking economic taxa. The following interpretations are based on evidence from the coprolites considered to be human.

1.17. Discussion

1.17.1. Diet

Dietary constituents indicate that hunter-gatherer groups recurrently visited the Connley Caves during the late summer or early fall and consumed a variety of taxa from multiple ecozones (Table 3.3). Diets regularly included meat and small seeds supplemented by lesser amounts of upland fruits and roots. The variable presence of wetland taxa shows that marsh habitats were often, but not always, exploited during cave visits. The prevalence of saltbush- and grass-seed consumption is well documented at concurrent house and cache features in the region (Helzer 2001, 2004; Jenkins 2004; Kennedy 2018; Kennedy and Smith 2016); however, the large quantity of rush, cattail, and sumac seeds in some of the Connley Caves coprolites suggests that these taxa represent previously unrecognized components of the Bergen Period food economy. As such, this study shows that cave inhabitants were eating many of the same resources found in the house, hearth, and cache features of prominent lowland sites in the Fort Rock Basin and suggests that the Connley Caves might have been an important foraging location for winter provisioning.

Coprolites from the Connley Caves contain dryland (saltbush, grass, blazingstar, wildrye, and knotweed), wetland (fish, cattail, rush, bulrush, and pondweed), and upland (sumac, juniper, carrot family, and possibly wild-onion, cherry, and pine) taxa. The ubiquity and abundance of

saltbush, grass, and cattail seeds suggest that these resources were dietary staples. Cattail and grass seeds are more ubiquitous among younger coprolites, indicating that cave inhabitants consumed these plants more regularly after ~3500 cal BP (Table 3.2). Juniper, sumac, and possibly wild-cherry seeds reflect visits to upland habitats. Geophyte exploitation is suggested by plant tissue resembling wild onion bulb scales in four samples and the high frequency of Liliaceae and Apiaceae pollen in two samples. Low representation of upland- and lithosol-community plants suggests infrequent use of these habitats; however, fleshy fruits and root-crop foods could be underrepresented due to digestion processes and difficulty of plant tissue identification. Overall, dryland taxa are present in almost all of the coprolites, while wetland and upland taxa are more sporadic dietary inclusions.

Most coprolites contain some form of faunal remains, indicating that animal resources were a regular part of the diet. Evidence of fish consumption does not appear in the coprolites until after ~4500 cal BP, and the presence of vertebrae in three coprolites suggests that fish were sometimes consumed whole. Fur and hair do not occur in large quantities, but the ubiquity of bone (75% of samples) suggests that meat was regularly consumed. Insects are not well represented and do not appear to have been a significant part of the diet at this time and place.

Habitat, seasonal availability, and ethnographically documented dietary uses of coprolite constituents are provided in Table 3.3. Ripening times of represented taxa indicate human occupation of the caves during late summer or early fall (Table 3.3).

Table 3.3. Habitat type, seasonal availability, and ethnographic uses of plant taxa in Connley Cave coprolites.

	Plant	Part Found	Habitat ^a	Seasonal Availability ^b				Part Used	Traditional Use ^c	Cooking process	Reference
				Spring	Summer	Fall	Winter				
Dominant	Cattail (<i>Typha</i> sp.)	Seed	WET					All	food	boiled, ground, parched, raw	Chamberlin 1911; Couture 1978; Fowler 1990; Mahar 1953, Steward 1938; Stewart 1941
		Pollen	WET								
	Sumac (<i>Rhus</i> sp.)	Seed	UPL					Fruit	food, medicine	boiled, dried, raw	Chamberlin 1911; Steward 1938; Train et al. 1941
Abundant	Saltbush (<i>Atriplex</i> sp.)	Seed, Fruit	DRY					Seed, root	food, medicine	ground, raw, parched	Chamberlin 1911; Couture 1978; Fowler 1982; Kelly 1932; Steward 1933; Stewart 1941
	Rush (<i>Juncus</i> -type)	Seed	WET					Seed, stem	food, beverage, candy	fermented, raw	Fowler 1989; Rhode 2002; Steward 1933
	Wild onion (cf. <i>Allium</i> sp.)	Bulb	LITH					All	food	boiled, raw, roasted	Chamberlin 1911; Couture 1978; Fowler 1989; Kelly 1932; Mahar 1953
Common	Wildrye (<i>Elymus</i> spp.)	Florets	DRY					Seed	food	ground, parched	Chamberlin 1911, Fowler 1992, Kelly 1932, Steward 1938
	Blazingstar (<i>Mentzelia</i> sp.)	Seed	DRY/UPL					Seed	food, relish, sauce	dried, ground, parched	Couture 1978; Fowler 1989; Kelly 1932; Murphey 1959, Rhode 2002, Stewart 1941
Present	Bulrush, tule (<i>Scirpus</i> -type)	Seed	WET					All	food	ground, raw	Bean and Siva 1972; Chamberlin 1911; Couture 1978; Fowler 1989; Steward 1938
	Juniper (<i>Juniperus</i> sp.)	Seed	UPL					Fruit	food, medicine	boiled, parched, raw	Chamberlin 1911; Fowler 1989; Kelly 1932; Mahar 1953
	Cherry (cf. <i>Prunus</i> sp.)	Fruit	UPL					Fruit, bark	food, medicine	boiled, dried, raw	Chamberlin 1911; Couture 1978; Fowler 1989; Kelly 1932; Mahar 1953; Steward 1938; Train et al. 1941
	Carrot Family (<i>Apiaceae</i>)	Pollen	LITH					Root, stem	food, medicine	boiled, dried, parched, raw	Fowler 1989; Kelly 1932; Mahar 1953; Train et al. 1941

	Plant	Part Found	Habitat ^a	Seasonal Availability ^b				Part Used	Traditional Use ^c	Cooking process	Reference
				Spring	Summer	Fall	Winter				
<i>Rare</i>	Knotweed (<i>Polygonum</i> sp.)	Seed	DRY					Seed	food	Ground, parched	Coville 1897; Steward 1933
	Pondweed (<i>Potamogeton</i>)	Seed	WET					Seed	n/a ^d		

^aHabitat classification is based on the four habitats defined by Prouty (1994): wet/lowland (WET), dry/lowland (DRY); upland (UPL), and lithosol (LITH).

^bSeasonal availability is based on data from USDA (2014).

^cTraditional consumption and cooking process are based on ethnographic data from Indigenous groups of Oregon, Nevada, Utah, and California.

^dDocumented as a source of fiber for crafting but not as a food source among Great Basin Indigenous groups.

With the exception of pondweed, all of the identified taxa are documented as important within the subsistence economies of Great Basin indigenous groups (Chamberlin 1911; Coville 1897; Couture 1978; Fowler 1990; Kelly 1932; Mahar 1953; Murphey 1959; Steward 1933; Stewart 1941; Train et al. 1941). Although pondweed is not considered an economic food source, it has been found in coprolites elsewhere in the Great Basin (Rhode 2003). Charred bulrush seeds are indicative of toasting, and crushed saltbush, cattail, and blazingstar seeds may be the product of milling. Blazingstar is known as an important food source among indigenous Great Basin groups (Couture 1978; Fowler 1989; Fowler and Rhode 2007; Kelly 1932; Steward 1938); however, this plant was only recently recognized in archaeological assemblages from the northern Great Basin (Kennedy 2018; Kennedy and Smith 2016). The presence of these seeds in three coprolites corroborates and extends the geographic range of blazingstar consumption.

Several plant taxa found in the coprolites are also known for their economic non-dietary uses. Bulrush and cattail, for example, are among the most important taxa for fiber materials. Catlow twine, the dominant basketry type in the northern Great Basin, is predominantly manufactured from bulrush (*Scirpus*-type, aka “tule”) and occasionally cattail (Camp 2017:27; Connolly and Barker 2004:242; Connolly et al. 2016; Cressman 1942:33). Directly dated Catlow twine from the Connley Caves chronologically overlaps with the coprolites (Table 3.1), showing that bulrush was used for both textile and dietary purposes during the middle Holocene. Cattail, bulrush, grasses, and juniper were all used for construction and clothing (Fowler 1990; Mahar 1953). While it is possible that seeds could become incorporated into the site or even incidentally ingested through such non-dietary economic uses, the large number of seeds from these taxa found within the coprolites suggests that the plants were also purposefully consumed.

Cluster analysis has been successfully used as an exploratory technique to identify patterns of co-occurrence among coprolite constituents (Rhode 2003; Riley 2008; Sutton and Reinhard 1995). Cluster analysis of the Connley Cave coprolites using the ten most abundant and ubiquitous taxa identified three groups of samples. The cluster dendrogram in Figure 3.7 shows the relationships between coprolite specimens, and Table 3.4 displays the coprolite constituents for each individual specimen grouped by cluster. All samples containing wetland plant taxa group into Cluster A, samples without seeds make up Cluster B, and seeds of both dryland and upland taxa are represented in Cluster C. Faunal remains are present in coprolites from all clusters, but fish are only present in Clusters A and B. Coprolites in Cluster A have the highest richness (taxa per sample), Cluster B has the lowest, and Cluster C is in between.

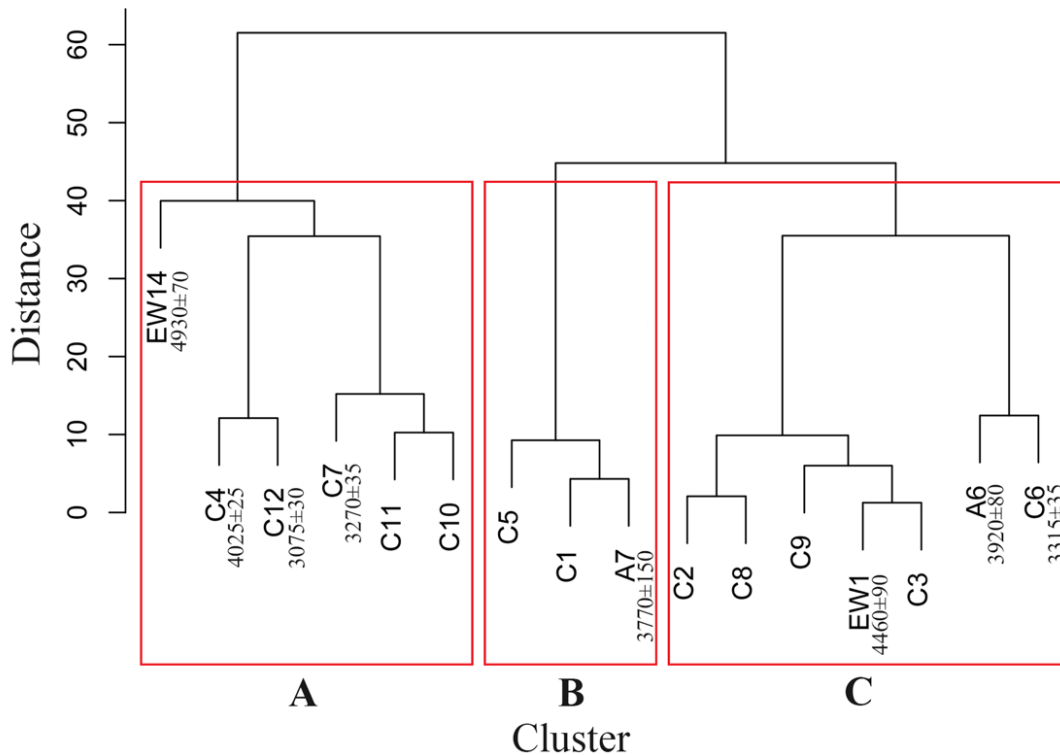


Figure 3.7. Cluster analysis of primary coprolite constituents from Connley Cave.

Table 3.4. Abundance quintile values of dietary constituents used in cluster analysis.

Cluster	Sample	Wetland			Dryland			Upland		Fauna	
		Cattail	Rush	Bulrush	Saltbush	Grass	Blazingstar	Juniper	Sumac	Fish	Bone
A	EW14	4	0	0	2	0	0	0	5	0	0
	C4	5	0	0	4	0	2	0	0	0	1
	C11	4	4	0	3	1	0	0	0	0	2
	C10	5	4	2	4	1	0	0	0	1	2
	C7	5	0	2	3	1	0	0	0	0	1
	C12	1	2	0	3	0	3	0	0	2	2
B	C1	0	0	0	0	0	0	0	0	1	3
	A7	0	0	0	0	0	0	0	0	3	3
	C5	0	0	0	0	0	0	0	0	2	0
C	EW1	0	0	0	4	4	0	0	0	0	1
	C3	0	0	0	4	3	0	0	0	0	0
	C2	0	0	0	2	0	0	0	0	0	0
	C8	0	0	0	4	1	0	0	0	0	0
	C9	0	0	0	3	2	1	0	0	0	2
	A6	0	0	0	2	4	0	2	0	0	3
	C6	0	0	0	0	0	0	2	0	0	1

Coprolite specimens did not cluster by chronology or season; rather, richness and habitat zone are the most apparent defining variables. The co-occurrence of wetland, dryland, and upland taxa in some coprolites shows that plant and animal resources from a wide range of habitats were consumed within the course of one or several meals. Coprolites of all ages are represented in Cluster A, providing evidence for chronological continuity in wetland resource use. The two samples considered most likely to be non-human in origin (C1 and A7) grouped into a clade within Cluster B. C5 also grouped into Cluster B; however, unlike C1 and A7 which contain no seeds, coprolite C5 contains two seed types (cf. wild cherry and “type k”) that were not included in the top ten taxa used for the cluster analysis. The presence of these seeds coupled with fishbones and abundant plant tissue resembling wild onion suggests an omnivorous diet for C5.

The patterns identified in the cluster analysis show that cave inhabitants were not always foraging in a single habitat zone. Absence of wetland taxa in Cluster C suggests that foraging did not always extend to the marsh. Such variability could reflect divisions of labor in which one segment of the population foraged in the marsh while others focused on dryland and upland resources. It could also reflect differences in foraging objectives of the whole group during separate visits to the site. Lastly, Cluster A and C might reflect complex foraging objectives that cannot be interpreted from the available data. Cluster B provides further support that these are non-human coprolites.

1.17.2. Settlement Subsistence

The diet reflected in the Connley Cave coprolites fits well within the regional settlement-subsistence pattern proposed by Jenkins (1994). The middle Holocene archaeological record in the northern Great Basin indicates a shift from a highly mobile foraging strategy (Lunette Lake

Period) to a more collector-like strategy (Bergen Period) (Binford 1980; Jenkins 2004; Prouty 2004). Whereas the Lunette Lake Period is characterized by extreme residential mobility, Bergen Period groups were more sedentary and practiced logistical strategies involving organized task groups that would travel to diverse patches and bring resources back to the central location (Binford 1980; Prouty 2004). Intensive processing focused on lowland resources with supplementary upland resources and long-term storage/caching may have been an adaptive technique to sustain higher population densities (Jenkins 2004; Prouty 2004; Testart 1982). Stores of plant food surpluses functioned as a buffer against resource depletion by growing populations during seasons of scarcity (Jenkins 2004; Prouty 2004). Jenkins argues that large caches were sometimes positioned away from the permanent residence to reduce the risk of raids while the group was away (Jenkins 2004) - a “collector-like” strategy coupled with need for mobility.

During the Bergen Period, groups spent fall through spring in small hamlets positioned along stable marshes in the southwestern end of the basin (Big M, DJ Ranch) and in the northwestern end of the basin near overwintering sites of large game (Bergen) (Jenkins et al. 2004). House pits, cache pits, groundstone, and fishing gear found at Big M and DJ Ranch suggest lowland productivity and long-term storage. The best evidence for intensive food processing and on-site storage of surplus food comes from DJ Ranch where cache pits have yielded charred knotweed and saltbush seeds, fruity tissue, biscuitroot (*Lomatium*), and tui chub (*Gila bicolor*) bones (Moessner 2004; Prouty 1995). Repeated fall and winter use of Bergen, the largest and most heavily occupied middle Holocene site in the Fort Rock Basin, contains evidence for consumption of saltbush, bulrush, goosefoot (*Chenopodium*), suaeda (waada), deer, elk, pronghorn, mountain sheep, jackrabbits, waterfowl, and small minnows (Helzer 2001, 2004;

O'Grady 2004). The archaeobotanical record from all of these sites is dominated by lowland taxa (grass, saltbush, goosefoot, suaeda, and bulrush seeds), but also contains lesser amounts of juniper and root crops indicative of upland exploitation. Storage pits at Bowling Dune show that food resources harvested from diverse ecological settings throughout the spring, summer, and fall were transported, sometimes considerable distances, to be kept in a location away from the winter hamlet or house (Jenkins 2004). The largest of these storage pits would have held 3.6 m³ of material, indicating serious caching activity (Jenkins 2004). These behaviors suggest that even at the height of sedentism in this region, groups still required some degree of mobility. Where were groups going when they were away from their houses? When and where were they gathering the food surpluses for long term storage?

The Connley Caves provide a unique perspective showing how this site type (rockshelters) fits into the middle Holocene regional settlement-subsistence pattern. Dietary evidence from the coprolites indicates that the Connley Caves might have functioned as a temporary habitation site for task groups hunting and foraging for late summer/early fall food items. These data provide support for the broader scheme proposed by Jenkins (1994) in which Bergen Period settlement-subsistence was focused on highly productive lowland resources such as fish and small seeds. The position and content of prominent middle Holocene sites suggest that groups were “mapped on” to these dense lowland resources; however, trace evidence of upland taxa shows that other habitats were also exploited. Jenkins (1994) argues that upland resources were procured by special task-specific foraging groups during short logistical moves from and back to the residential camp (Binford 1980). The Connley Caves would have been a desirable logistical location during the fall when large mammals and diverse plant taxa could be acquired within the hills and nearby Paulina Marsh.

1.17.3. Parasites

There are two genera within the family Taeniidae that could be represented by the eggs in sample C12: *Taenia* and *Echinococcus*. Eggs of tapeworm species within these families cannot be distinguished from each other at this stage in the lifecycle. Tapeworm eggs appear in latrine and coprolite contexts at archaeological sites throughout western North America but have not been identified beyond family level. In the Great Basin, Taeniid-type eggs are reported from coprolites at Hogup Cave, Danger Cave, and Glen Canyon (Fry 1970). Eggs are known from the Southwest from Elden Pueblo and Antelope Cave in Arizona, and Turkey Pen Cave in Utah (Hevly et al. 1979; Reinhard et al. 1987; Reinhard, personal communication 2018).

Echinococcus sp. infection has been distinguished at two North American sites where calcified cysts are preserved with skeletal remains in Alaska (Ortner 2003) and North Dakota (Williams 1985). None of the human-infecting *Taenia* species has been thought to have existed in North America prehistorically (Reinhard 1990), and the earliest evidence for human *Echinococcus* sp. infection post-dates C12 by ~1800 years (Ortner 2003). Therefore, the appearance of Taeniidae eggs at the Connley Caves represents (1) an unprecedented instance of human *Taenia* sp. infection in the Americas; (2) the earliest occurrence of *Echinococcus* infection in North America; (3) incidental ingestion or environmental contamination; or (4) a non-human origin of the coprolite.

The known distribution and evolutionary history of *Taenia* has changed in the last decade. Traditionally considered strictly in association with domestic swine (*T. solium*) or cattle (*T. saginata*) (Baer 1940; Cameron 1956), *Taenia* infection in humans is now understood to significantly predate domestication events (Hoberg et al. 2001; Hoberg 2006). *Taenia* infection is reported in Siberia in the absence of domesticated animals (Slepchenko et al. 2016, 2017), where

it is attributed to the consumption of contaminated meat of wild ungulates (Konyaev et al. 2017). These findings suggest that *Taenia* sp. infected a broader range of hosts across a larger geographic area than traditionally thought. Eggs in C12 could be from a non-human infecting form of Taeniidae that became incorporated through incidental ingestion prior to deposition or through post-depositional environmental contamination. For example, *T. pisiformis* (rabbit tapeworm) is ubiquitous worldwide and causes infection in lagomorphs, rodents, and carnivores. The possibility that eggs were present in the soil and entered the coprolite post-depositionally cannot be excluded but is unlikely due to the number of eggs and their absence in all other specimens. The presence of Taeniid eggs in C12 is intriguing and merits further investigation.

1.17.4. Future Directions

This study raises questions that can be addressed with additional analytical techniques. The context and contents of most coprolites are consistent with a human origin, but this should be confirmed with ancient DNA and lipid biomarker analysis (Battillo 2017; Battillo and Fisher 2015; Beaton 1991; Bull et al. 1999, 2002; Gilbert et al. 2008; Shillito et al. 2013). Ancient DNA analysis could facilitate more specific taxonomic identification and detection of species that cannot be observed with traditional microscopy techniques (Battillo 2017; Murray et al. 2013). Additionally, the use of starch and phytolith analysis would clarify the use of geophytes, plant fibers, rhizomes, and leafy greens (Herzog 2014; Herzog and Lawlor 2016; Louderback et al. 2017; Riley 2012). Hormone analysis (e.g. Rhode 2003; Sobolik et al. 1996) could be used to examine the relationship between dietary variance and biological sex. Finally, aDNA could be used to examine the genetic affiliation of cave occupants (Gilbert et al. 2008; Poinar et al. 2001). In sum, the multiscalar data presented in the study would be complemented by investigations at the molecular level.

1.18. Conclusion

As the first human coprolite analysis of this time period in the northern Great Basin, this study contributes uniquely discrete datasets clarifying resource exploitation and subsistence choices of hunter-gatherers who visited the Connley Caves during the middle to late Holocene transition (ca. 5700 to 3200 cal BP). This study has shown that the caves were recurrently inhabited during the late summer/early fall by foragers who consumed seeds, fruits, plant tissue, and meat of taxa from wetland, dryland, and upland ecozones. Foragers repeatedly visited the caves around the same time of year, but at least a segment of the group did not use wetland resources during some visits. Large amounts of saltbush, grass, and cattail seeds were found in coprolites of all ages, suggesting that these plants were regular and prominent dietary components. The coprolite assemblage suggests that ca. 5700 to 3200 cal BP, the Connley Caves functioned as a temporary habitation site for logistical foraging groups. These data expand the known dietary breadth of the Bergen Period food economy and provide an example of how rockshelters fit into the larger settlement-subsistence patterns of the time.

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CHAPTER IV

HOLOCENE VEGETATION HISTORY AND CLIMATE OF CENTRAL OREGON: THE EMERGING RECORD FROM PAULINA MARSH, OREGON

Longstanding questions driving palaeoecological research in the Great Basin include understanding regional expressions of globally recognized climatic events, reconstructing the biogeography and expansion of certain plant taxa, and elucidating the relationship between climatic shifts and human adaptive strategies. Because environmental responses to global climatic shifts were not uniform across the Great Basin (Hudson et al. 2019; Lyle et al. 2012; McGee et al. 2018; Wigand and Rhode 2002), locally refined paleoclimate proxy records are required to answer such questions. Although robust paleoenvironmental records are established for some areas of Nevada, Utah, and eastern California (Adams et al. 2008; Benson et al. 1990, 1998; Godsey et al. 2011; Goebel et al. 2011; Louderback and Rhode 2009; McGee et al. 2012; Oviatt et al. 2005, 2015; Reheis et al. 2014; Rhode 2000; Rhode and Madsen 1995; Wigand and Rhode 2002), our understanding of the northern Great Basin is still relatively coarse due to Holocene lake desiccation, pervasive deflation, and less frequently preserved packrat (*Neotoma*) middens (Allison 1979; Cohen et al. 2000; Friedel 1994; Negrini et al. 2000; Thompson 1990). The paucity of high-resolution paleoenvironmental records in the northern Great Basin is especially problematic because some of the richest and earliest archaeological sites in western North America have been and continue to be excavated there (Aikens et al. 2011; Bedwell 1973; Gilbert et al. 2008; Jenkins et al. 2013, 2017; McDonough et al. 2018; Rosencrance et al. 2019; Smith et al. 2020).

To contribute to a better understanding of vegetation change in response to climatic variation in the northern Great Basin, I present a new pollen record and other sediment-core data from Paulina Marsh located in the Fort Rock Basin of Oregon (Figure 4.1). I focused my sediment coring project on Paulina Marsh for four important reasons. First, its location in Silver Lake Valley, the smallest of the Fort Rock sub-basins, makes it highly responsive to shifts in climate and reflective of local vegetation communities. Second, as the only recipient of perennial stream flow in the basin, it is the most likely area to have remained wet and have an unbroken, preserved pollen sequence for the late Pleistocene and Early Holocene. Third, preliminary geomorphological survey by Benjamin (1994) indicated the potential for buried Holocene deposits. Fourth, archaeological records indicate that Paulina Marsh has been a critical resource for millennia. Here I focus on core PAUL-2A retrieved from the southwestern marsh (Figures 4.2 and 4.3) and provide preliminary information on four other cores, specifically their locations and initial dating of two of them.

I use multiple lines of evidence from PAUL-2A including pollen, geomorphology, particle size, and elemental (carbon and nitrogen) data to examine vegetation change and site depositional history during the Early and Late Holocene. A buried paleosol at the base of the core dates between ~10,200 and 8400 calendar years before present (cal BP) and provides the first Early Holocene pollen record in the Fort Rock Basin. Above the soil there is a significant break in sedimentation where any deposits that had accumulated between ~8400 and 3900 cal BP were eroded away. The upper segment of the core contains an unbroken record for the last ~3900 years and reflects a wetland environment until ~2000 cal BP, after which mesic plant taxa decrease, and dryland shrubs and herbs dominate. The emerging vegetation history from Paulina Marsh compares well with other regional environmental and human paleoecological records.

Together, these multiproxy data offer new insights on the history of Paulina Marsh and inform models of climatic impacts and human adaptations during the Holocene.

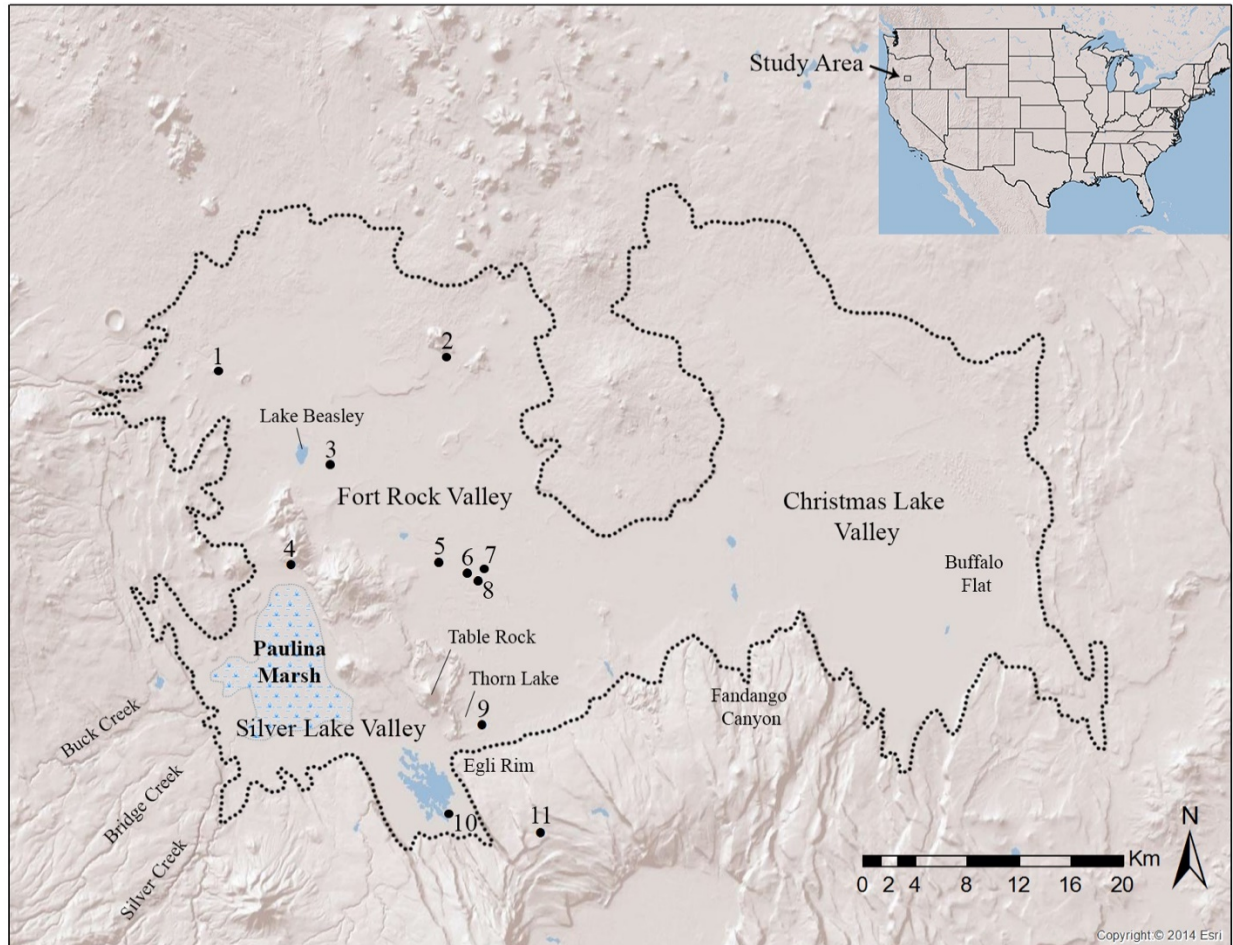


Figure 4.1. Map of the Fort Rock Basin showing location of Paulina Marsh and archaeological sites discussed in the text: (1) Fort Rock Cave; (2) Cougar Mountain Cave; (3) Bergen; (4) Connley Caves; (5) Bowling Dune; (6) DJ Ranch; (7) Locality III; (8) Locality I; (9) Big M; (10) Carlon Village; (11) Boulder Village.

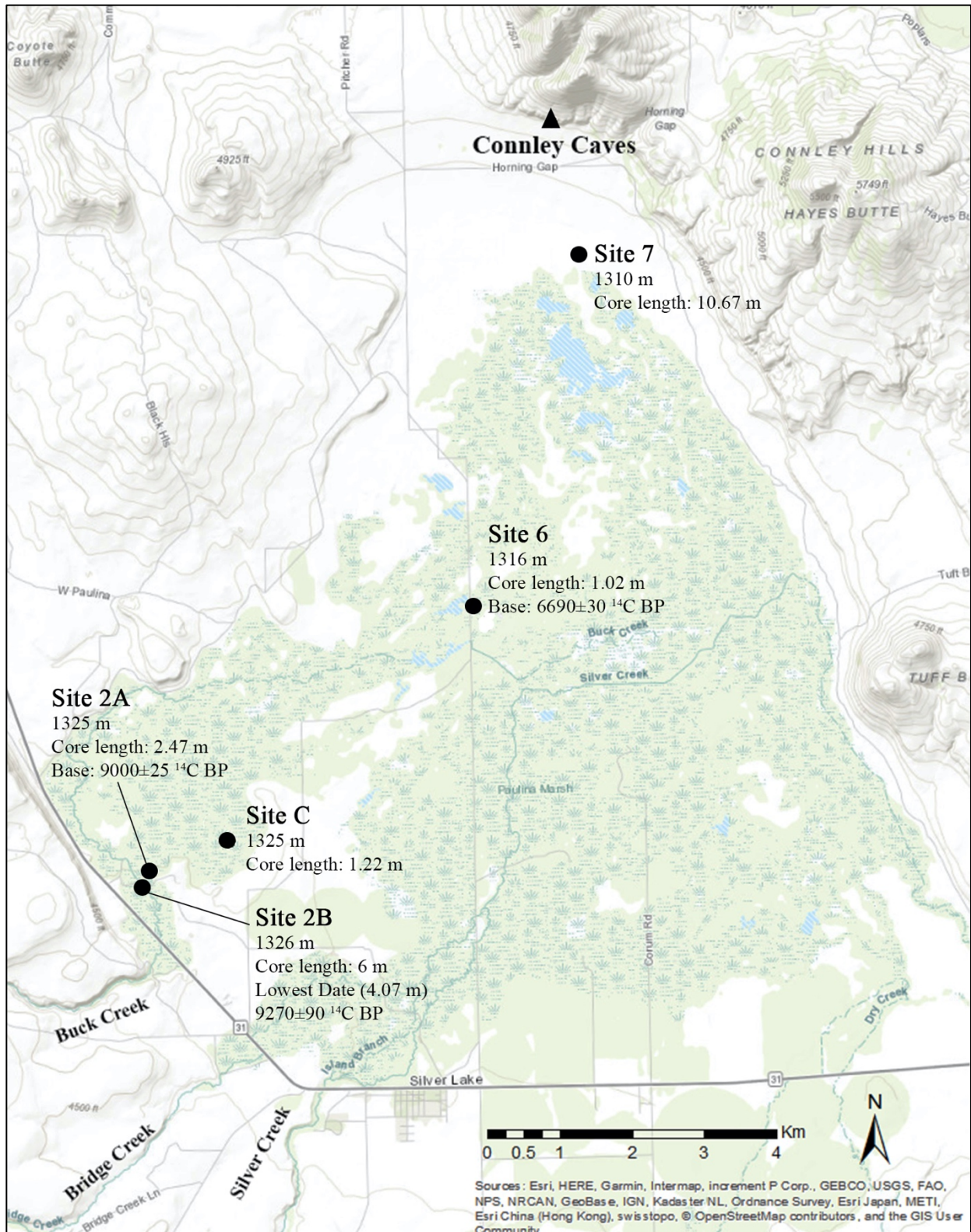


Figure 4.2. Location of sediment cores from Paulina Marsh.

1.20. Climate Change and Human Paleoecology in the Northern Great Basin

Globally recognized climatic events were not synchronously expressed across the Great Basin and certain events may have occurred later or have been less pronounced in the northwest relative to areas farther south and east (Grayson et al. 2011; Hudson et al. 2019; Lyle et al. 2012; McGee et al. 2018; Wigand and Rhode 2002). During the Pleistocene, the timing of pluvial-lake maxima occurred in a progression from south to north, with the most recent highstands occurring in the northwestern Great Basin (Hudson et al. 2019; Lyle 2012; McGee et al. 2018). During the Younger Dryas (ca. 12,900 to 11,700 cal BP), some lakes in the northwest receded (e.g., Lake Chewaucan [Hudson et al. 2019]) while lakes to the southeast rose (e.g., the Great Salt Lake [Broughton and Smith 2016; Goebel et al. 2021; Oviatt 2014]). The Holocene Climatic Optimum (ca. 9000 to 5000 cal BP) is characterized by warm and dry conditions throughout the Great Basin; however, the onset of severe drought conditions may have occurred slightly later in the northwest, ca. ~8500 cal BP (Aikens et al. 2011; Dugas 1998; Mehringer and Cannon 1994; Mehringer and Wigand 1986; Wigand and Rhode 2002). Climatic oscillations became more rapid after ~3000 cal BP (Wigand 1987), but do not appear to reflect certain widespread events such as the Medieval Climatic Anomaly (ca. 1100 to 600 cal BP), marked elsewhere by increased aridity (Mensing et al. 2008, 2013; Thompson et al. 2016), or the Little Ice Age (ca. 500-150 cal BP), typically characterized by temperature drop (Goebel et al. 2021; Thompson et al. 2016). Instead, northern pollen records indicate mesic and arid conditions during those respective events (Minckley et al. 2007; Wigand and Rhode 2002).

Though most vegetation shifts occur altitudinally (e.g., upslope retreat of mesic-adapted taxa during xeric periods), some taxa traversed latitudinally during the Holocene. In the central Great Basin, single-leaf pinyon pine (*Pinus monophylla*) expanded its geographic range during

the Holocene, reaching its modern eastern extent in Utah and western extent in the Sierra Nevada Mountain Range of California sometime around 6000 and 300 cal BP, respectively (Grayson 2011). The northern extent of *P. monophylla* ends just before the Humboldt River in Nevada. In the northern Great Basin, the timing of western juniper (*Juniperus occidentalis*) expansion during the Holocene is poorly constrained. *Juniperus* is now a hallmark of central Oregon's landscape but it may not have reached the Fort Rock Basin until the Holocene, sometime between ~10,000 and 6000 cal BP (Jenkins, Droz, et al. 2004; Miller et al. 2005; Prouty 2004). Management of *Juniperus* is of great economic and ecological importance today, and understanding its paleobiogeography would inform management efforts, in addition to providing proxy data for paleoclimates.

The Fort Rock Basin is renowned for its archaeology (e.g., Aikens and Jenkins 1994; Bedwell 1970, 1973; Connolly et al. 2017; Helzer 2004; Jenkins, Connolly, et al. 2004; Jenkins et al. 2017; McDonough 2019; Rosencrance et al. 2019; Wingard 2001) but lacks local paleoenvironmental records needed to fully contextualize those data. For example, some of the oldest directly dated textiles in North America are from Cougar Mountain Cave (Rosencrance et al. 2019), sagebrush sandals from Fort Rock Cave represent the oldest footwear in the world (Connolly and Cannon 1999; Connolly et al. 2016; Cressman 1951), and people have visited Connley Caves for at least 12,600 years (Bedwell 1970, 1973; Jenkins et al. 2017; McDonough et al. 2018; Chapter III) (Figure 4.1). Nearly a century of archaeological research in the Fort Rock Basin has set the foundation for proposed human palaeoecological models; however, those models cannot be fully tested until local vegetation and hydrologic histories are available (Aikens et al. 2011; Cressman 1942; Cressman et al. 1940; Jenkins et al. 2004).

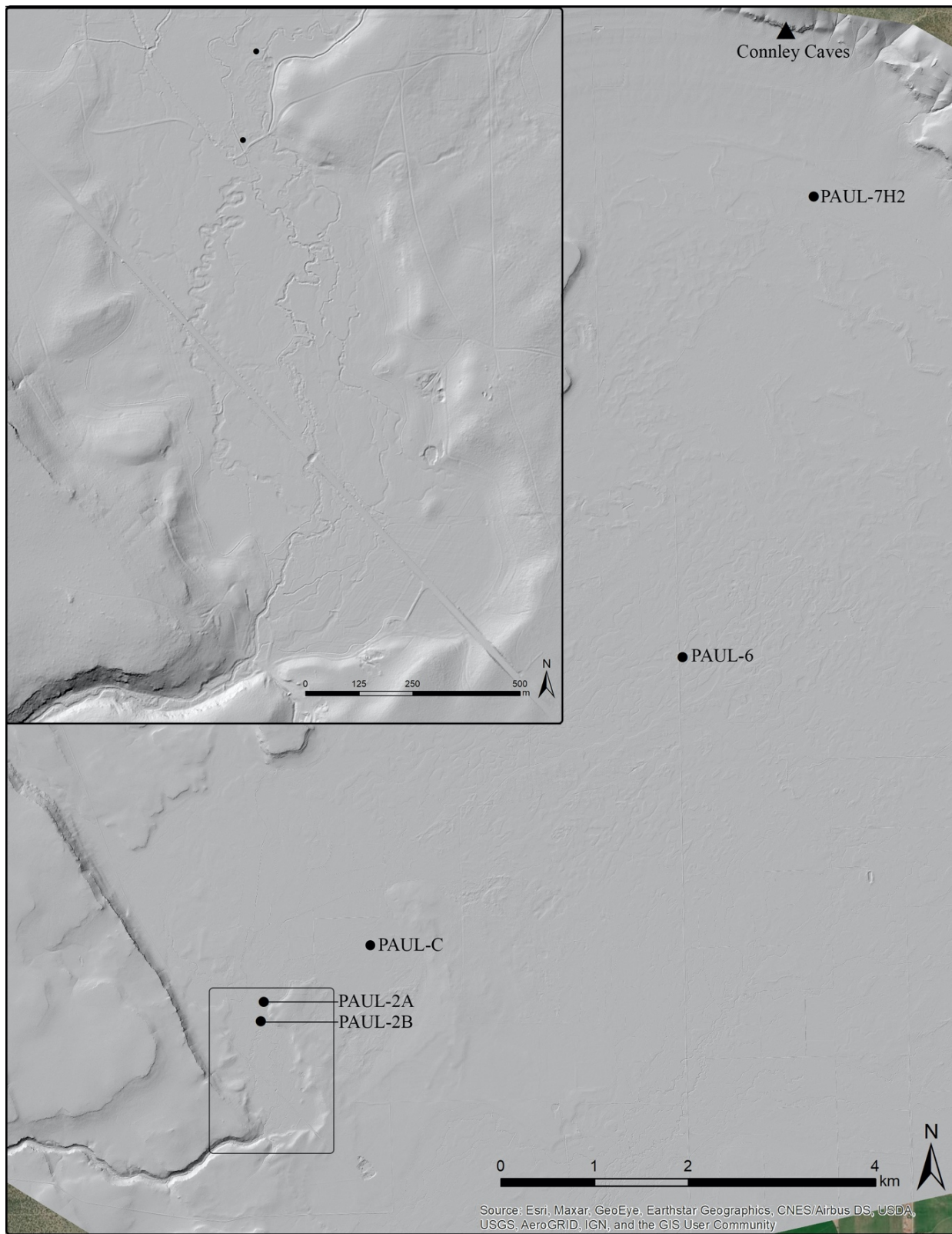


Figure 4.3. Lidar imagery of coring locations in Paulina Marsh.

Due to its position as the northwestern-most drainage system in the Great Basin and its rich history of intensive archaeological research, paleoenvironmental reconstruction in the Fort Rock Basin stands to provide a unique perspective on questions of paleoecology, biogeography, and cultural adaptation. Developing a locally refined paleoenvironmental record for the Fort Rock Basin is important for testing predictions about the hydrologic and cultural impacts of climate change in the northern Great Basin and for serving as a complement to existing palaeoecological records elsewhere in the region.

1.21. Study Area

The Fort Rock Basin encompasses an area of ~3900 km² in the northern Great Basin, a region characterized by internal drainage and the remnants of Pleistocene pluvial lakes. The setting is a semi-arid high desert with less than 25.4 cm of annual precipitation and ~520 m separating the valley floor (~1310 meters above sea level [m ASL]) and mountain peaks (~1830 m ASL) (Grayson 1979, 2011; Hampton 1964). The Fort Rock Basin is positioned within the ecotone between the Basin and Range and the High Lava Plains provinces, with lava plains, lava shields and cinder cones characterizing the uplands to the north and fault scarps and block mountains to the south and east. Ridgelines divide the Fort Rock Basin into three sub-basins: Silver Lake, Christmas, and Fort Rock (Figure 4.1). The Connley Hills, which are comprised of the eroded lava cone of Horning Bend and composite lava shield of Hayes Butte (Hampton 1964), form the northwestern border of the Silver Lake sub-basin where Paulina Marsh is located.

Silver, Buck, and Bridge creeks drain from the foothills of Yamsay Mountain, a shield volcano in the Cascade Range, and into the southwestern Silver Lake sub-basin. The streams feed Paulina Marsh, meandering north toward the Connley Hills and eventually southward into

Silver Lake (Benjamin 1994; Jenkins 1994; Jenkins and Aikens 1994). The drainage of the basin is internal, with some possible subsurface discharge to the Summer Lake Basin and the Deschutes River drainage system (Allison 1979; Friedel 1994; Hampton 1964). The majority of the basin rarely supports standing water, except for in the Silver Lake Valley where the perennial streams enter Paulina Marsh. During exceptionally wet periods in the past, overspill from the Silver Lake Valley entered the Fort Rock Valley through a gap between Table Rock and Egli Rim (Jenkins, Droz, et al. 2004). Water passed through this gap and into Thorn Lake, where it proceeded through a series of interconnected playas, flowed into Paleo Lake Beasley near the town of Fort Rock, and ultimately entered Christmas Valley. Activities such as farming, irrigation, and introduction of cattle have significantly altered the modern marsh hydrology.

The perennial Buck, Bridge, and Silver creeks originate from Yamsay Mountain, located ~35 km southwest of Paulina Marsh. Yamsay (*Yámsi*) Mountain is significant within the history and mythology of the Klamath people (Gatschet 1890). The mountain's summit (2498 m), surrounding slopes, and the upper reaches of the Buck Creek drainage are designated as Traditional Cultural Property for the Klamath Tribes (USDA Forest Service 2007, 2014). The upper ~1000 m of Yamsay Mountain are characterized by ponderosa pine (*Pinus ponderosa*) and mixed ponderosa pine/white fir (*Abies concolor*) forests (USDA Forest Service 2007). Historically these stands consisted of pure ponderosa overstory and sparse understory of ponderosa with smaller components of lodgepole pine (*Pinus contorta*) and white fir (USDA Forest Service 2007); however, the latter taxa have expanded in recent decades (USDA Forest Service 2007). Hardwood species such as willow (*Salix* spp.) and aspen (*Populus* sp.) grow in meadows and along stream drainages. The foothills of Yamsay Mountain are characterized by bitterbrush (*Purshia* spp.) and sagebrush (*Artemisia* spp.) steppe plant communities with

rabbitbrush (*Chrysothamnus* spp.) and widely spaced *Juniperus occidentalis* (Franklin and Dyrness 1988).

Core site 2A, the focus of this study, is located within the gently sloped ($\bar{x} = 1\%$) floodplain where Buck Creek enters the southwestern corner of Paulina Marsh. Water-gauge data from Buck Creek show that between 1990 and 1999 mean annual stream flow in cubic feet per second ranged from a low of 5.64 in 1994 to a high of 27.2 in 1997 (Oregon Water Resources Department 2021). Buck Creek enters Paulina Marsh at the southern end of a prominent mesa, where it loses much of its velocity and disperses into smaller (~2-3 m wide and ~1-2 m deep) distributary channels extending northward toward the Connley Hills (Figure 4.4). Buck Creek and floodwaters are constrained near the 2A core site by the peninsula of a hill to the east, which may cause higher deposition rates.

Vegetation at Paulina Marsh is a mosaic of wetland patches and grassy meadows with emergent herbs and grass-like plants such as rushes (e.g., *Cyperus*, *Scirpus*, *Schoenoplectus*) and sedges (e.g., *Carex*) (Figure 4.5). Thickets of willow and riparian shrubs line the upper margins of the perennial streams, which historically supported tui chub (*Gila bicolor*), speckled dace (*Rhynchithys osculus*), and redband trout (*Oncorhynchus mykiss newberryi*) (Greenspan 1994). Alkaline playas and dune formations along the northern margins of Paulina Marsh support salt desert shrub communities of greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), and budsage (*Artemisia spinescens*). This fades into a tall sagebrush (*Artemisia tridentata*) steppe community with interspersed *Chrysothamnus* spp., low sagebrush (*Artemisia arbuscula*) and horsebrush (*Tetradymia glabrata*) (Franklin and Dyrness 1988). Modern vegetation in the Connley Hills and lower slopes of the Yamsay Mountain foothills include *Juniperus occidentalis* trees and understory dominated by *Artemisia* spp., *Chrysothamnus* spp.,

and grasses (Poaceae) such as bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and western needlegrass (*Achnatherum occidentale*) (Bureau of Land Management 2000; Franklin and Dyrness 1988).



Figure 4.4. Top: looking south across Paulina Marsh from above the Connley Caves toward Hagar Mountain. Bottom: looking north toward Connley Caves 6, 5, and 4.



Figure 4.5. Coring in Site 2: (a) area just north of site 2A, arrow points to coring location; (b) coring with modified Livingstone in 2018; (c) view of marsh looking north-northeast; (d) coring with Geoprobe in 2019.

1.21.1. Hydrologic History

Pluvial Lake Fort Rock filled the valley floor of the Fort Rock Basin during the Pleistocene, though the depth and chronology of the lake are poorly understood. Researchers have proposed a sequence of high stands based on the correlation of shorelines with radiometric dates on archaeological sites and gastropods from beach ridges (Allison 1979; Forbes 1973; Friedel 1994). The highest lake stand is represented by a weakly preserved shoreline feature at

~1384 m ASL, at which point the lake would have been ~76 m deep. Another shoreline between 1364 and 1366 m ASL is more apparent. The third and most substantial shoreline occurs between 1353-1356 m ASL and is associated with the formation of Connley Caves, Cougar Mountain Cave, and Fort Rock Cave. The highest shoreline (~1384 m) may have formed sometime before 42,000 cal BP, with the second highest (1364-1366 m) estimated to have formed ~18,000 cal BP, creating a lake with an average water depth of ~55 m (Allison 1979; Forbes 1973; Friedel 1994). The third-most-prominent shoreline (1353-1356 m ASL) likely formed during the late Pleistocene; a suite of radiocarbon ages on terrestrial materials from Connley, Fort Rock, and Cougar Mountain caves show that the lake receded from this elevation by at least 13,100 cal BP (Bedwell 1970, 1973; Connolly et al. 2017; Jenkins et al. 2017; Rosencrance et al. 2019). Lunette dunes began to form in the channel system between Silver Lake and Fort Rock valleys by ~12,000 cal BP (Droz 1997; Jenkins et al. 2004; Mehringer and Cannon 2004); however, dated ostracods at Buffalo Flat in Christmas Valley indicate enough water remained to form a shallow lake in the eastern Fort Rock Basin ~11,500 cal BP (Freidel 1994; McDowell and Benjamin 1991). Radiocarbon-dated charcoal from archaeological sites in Buffalo Flats indicate that the eastern basin was dry by at least 9200 cal BP (Oetting 1994). Together, these data suggest desiccation of Lake Fort Rock between ~12,000 and 9200 cal BP, with successive lacustrine, marsh, and dune environments ensuing throughout the Holocene (Droz 1997; Jenkins, Droz, et al. 2004; Mehringer and Cannon 1994).

Paulina Marsh is the only area of the Fort Rock Basin to regularly hold perennial water today and would have been the most well-watered area during climatic fluctuations of the past (Jenkins and Aikens 1994). Preliminary geomorphic fieldwork in Paulina Marsh revealed complexity and variability of depositional and erosional processes throughout the marsh

(Benjamin 1994). Based on stratigraphic profiles from dune and interdune formations in the marsh and along Silver Creek, Benjamin (1994) identified significant episodes of marsh expansion and contraction, even deflation, especially in the northeast area of the marsh. She proposed that younger dune formations are covering older, once-exposed marsh deposits in some elevated areas of the central marsh and along the marshes' margins. In the central marsh, Benjamin (1994:280) identified a layer of pumice ~95-105 cm below the surface overlying a ~105-cm deposit of silt loam. If the pumice corresponds to the eruption of Mount Mazama (ca. 7630 cal BP [Egan et al. 2015]), there is great potential that the underlying deposits contain sediment dating to the Early Holocene (ca. 11,600 to 8200 cal BP [Walker et al. 2012, 2019]) or older.

1.21.2. Research Questions

Questions driving the initial phase of palynological research at Paulina Marsh are six-fold. First, does the marsh contain a continuous series of terminal Pleistocene/Holocene sedimentary deposits, so that a complete record of the last ~16,000 years of paleoenvironmental history can be developed? Second, what can the geomorphology reveal about the hydrologic history and depositional processes of the marsh? Third, is pollen preserved within the marsh deposits, so that representative samples can be developed to interpret vegetation history of the region? Fourth, how do changes in marsh vegetation compare with climatic proxy data from pond and high-elevation lake records in the region? Fifth, do shifts in marsh vegetation align with human palaeoecological models that archaeologists have proposed for the northern Great Basin? And sixth, how are globally recognized climatic events expressed in the local vegetation history of the Fort Rock Basin?

1.22. Methods

Fieldwork in 2018 and 2019 resulted in the extraction of three cores (PAUL-2A, PAUL-6, and PAUL-C) using a modified Livingston piston coring device (12.7-cm-core diameter) and two cores (PAUL-2B and PAUL-72H) using a Geoprobe 7822DT (5.22-cm-core diameter) (Figure 4.5). PAUL-2A, the focus of this study, was extracted in four successive drives from the Buck Creek floodplain. The southwestern marsh is where perennial streams enter, making it an area likely to be consistently inundated with moisture and less susceptible to repeated cycles of wetting and drying that can cause significant breakage and corrosion of pollen grains (Campbell and Campbell 1994; Holloway 1989). I focused my analyses on PAUL-2A first because it was the longest core obtained in 2018, whereas the cores retrieved in 2019 were not as readily accessible for sampling. The locations of all cores retrieved from Paulina Marsh are shown in Figure 4.2.

I split, described, imaged, and sampled PAUL-2A at the International Ocean Discovery Program core repository in College Station, Texas. Sediment texture descriptions follow the USDA classification (Schoeneberger et al. 2012). I split the working half of the core into 2-cm increments that were further subsampled for various analyses. All five cores from Paulina Marsh are now curated at the Oregon State University Marine Geology Repository in Corvallis, Oregon.

I submitted 19 samples of macrofossil, charcoal, and bulk sediment samples for radiocarbon dating, of which six failed to produce dates due to insufficient carbon (Table 4.1).

I chose to date charcoal and macrobotanical constituents when possible, but such remains were scarce and bulk sediment samples were often the only option. Thirteen radiocarbon ages provide chronological control for the cores. For PAUL-2A, these include five samples submitted to the Penn State AMS Isotope Paleoecology Lab (PSUAMS) and four samples submitted to the

University of Georgia Center for Applied Isotope Studies (UGAMS); for PAUL-2B, four samples to PSUAMS; for PAUL-6, one bulk sediment sample to UGAMS; and for PAUL-7H2, five samples to PSUAMS. All radiocarbon dates are rounded following the conventions of Stuiver and Polach (1977) and calibrated using the Bayesian statistical software OxCal v4.4 (Bronk Ramsey 2009) using the IntCal20 curve (Reimer et al. 2020). I used the calibrated ages and the surface age (2018) from PAUL-2A to create a Poisson deposition model ('P_Sequence') in Oxcal v4.4 (Bronk Ramsey 2008; Bronk Ramsey and Lee 2013) (Appendix C). The P_Sequence age-depth model for core PAUL-2A included all dates listed in Table 4.1, except PSUAMS-8107, which is clearly out of sequence.

Table 4.1. Radiocarbon ages from Paulina Marsh sediment cores.

Core/ Drive	Lab Number	Material	Depth (cm)	m ASL (top of sample)	Sediment Description	¹⁴ C yr BP	95.4% Probability (cal BP) ^a
2A/1	PSUAMS-8105	Charcoal	60-62	1324.40	Brownish black (10YR 3/1) loam with dark brown organic bands	1235 ± 25	1270-1065
2A/2	PSUAMS-8106	Charcoal	95	1324.05	Brownish black (10YR 3/1) loam	1690 ± 20	1690-1530
2A/2	UGAMS- 40204	Sediment	111- 113	1323.89	Brownish gray (10YR 4/1) silty clay loam with botanical material	2400 ± 20	2490-2350
2A/2	PSUAMS-8255	Humates	135-137	1323.65	Brownish gray (10YR 4/1) fine sandy loam	2725 ± 20	2860-2765
2A/3	PSUAMS-8107	<i>Cuscuta</i> seeds	194-196	1323.06	Brownish black (10YR 3/1) loamy coarse sand	2335 ± 25	2420-2315
2A/3	UGAMS- 38626	Charcoal	199	1323.01	Charcoal in yellowish gray (10YR 4/1) loamy coarse sand	2930 ± 25	3170-2965
2A/3	PSUAMS-8256	Humates	218-220	1322.82	Black (10YR 2/1) silt loam, abundant organics, strong angular blocky structure	7690 ± 30	8545-8410
2A/3	UGAMS- 40205	Sediment	224-226	1322.76	Black (10YR 4/3) silt loam, abundant organics, strong angular blocky structure	8400 ± 20	9490-9315
2A/4	UGAMS- 38625	Sediment	244-246	1322.56	Brownish black (10YR 3/2) silt loam, blocky structure, redox features	9000 ± 25	10,240-9970
2B/2	PSUAMS-8925	Humates	164-166	1324.36	Very dark gray (10YR-3/1) silt loam with common very fine plant fragments	1345 ± 15	1345-1295
2B/2	PSUAMS-7099	Humates	280-282	1323.20	Black (2.5YR 2/1) sandy loam, saturated, weak sub-angular-blocky structure, pedogenic	8010 ± 35	9010-8720

Core/ Drive	Lab Number	Material	Depth (cm)	m ASL (top of sample)	Sediment Description	¹⁴ C yr BP	95.4% Probability (cal BP) ^a
2B/3	PSUAMS-7100	Humates	407-409	1321.93	Very dark gray (10YR-3/1) loamy sand	9270 ± 90	10,680-10,240
2B/4	n/a	Sediment	591-593	1320.09	Submitted to Penn State. Unable to date.	-	-
6A/2	UGAMS- 38627	Sediment	99-101	1315.01	silty clay loam	6690 ± 30	7615-7485
7H2/1	n/a	Sediment	139-140	1308.61	Submitted to Penn State. Unable to date.	-	-
7H2/2	n/a	Charcoal?	278	1307.22	Submitted to Penn State. Unable to date..	-	-
7H2/3	n/a	Sediment	395-396	1306.05	Submitted to Penn State. Unable to date.	-	-
7H2/3	n/a	Sediment	403-405	1305.97	Submitted to Penn State. Unable to date.	-	-
7H2/5	n/a	Sediment	720-721	1302.80	Submitted to Penn State. Unable to date.	-	-

^aAll radiocarbon ages were calibrated using OxCal v4.4 (Bronk Ramsey 2009) online program with IntCal20 curve (Reimer et al. 2020).

To characterize vegetation history, I analyzed 39 samples (1 cc each) from PAUL-2A for pollen. Pollen extraction followed Faegri and Iversen (1989) and was carried out at the Texas A&M Palynology Research Laboratory (TAMU PRL). After extracting 1 cc of sediment via displacement and the addition of two *Lycopodium* tracer spore tablets, samples were sieved through 250 µm mesh and processed using 5% potassium hydroxide (KOH), 15% hydrochloric acid (HCl), 48% hydrofluoric acid (HF), acetolysis solution (9:1 mixture of acetic anhydride and sulfuric acid) (Erdtman 1960), and one round of heavy density separation using 2.0 gravity zinc bromide solution. Samples were stained with two drops of safranin, curated in glycerin, and mounted on slides with glass cover slips sealed with clear commercial nail lacquer.

Pollen identification was facilitated through a binocular compound microscope at 400 power. Pollen identifications to the lowest possible taxonomic level proceeded with standard identification keys (Kapp et al. 2000), the TAMU PRL comparative collection, and the PalDat Palynological Database online resource (www.paldat.org), as well as through consultation with Vaughn M. Bryant. A minimum count of 200 pollen grains was made for 25 of the 39 samples (following Barkley 1934; Bryant and Hall 1993; Faegri and Iversen 1989). Pollen sums included all taxa. The 14 remaining samples had poor pollen preservation and/or low pollen concentration values (PCV). I plotted pollen data using the “rioja” package (Juggins 2020) in R 3.6.3 (R Core Team 2020) and determined pollen zones through constrained hierarchical cluster analysis of samples using stratigraphically constrained cluster analysis by the method of incremental sum of squares (CONISS) developed by Grimm (1987). I used the broken stick model (Bennett 1996) to test the statistical significance ($p < 0.05$) of the pollen zones identified in the cluster analysis.

Forty corresponding sediment samples (minimum 10 g each) were analyzed for total carbon, organic carbon, and nitrogen at the Texas A&M Agrilife Soil, Water and Forage Testing (SWFT) Laboratory (Agrilife Extension 2012), and 39 sediment samples (3-4 g) were granulometrically analyzed at the Soil Characterization and Quaternary Pedology Lab, Desert Research Institute, Reno, Nevada (DRI). I pretreated the latter samples at the TAMU PRL by sieving them through 2- and 1-mm mesh sieves followed by treatment with hot (75° C) 15% HCl to remove carbonates, and up to three treatments of hot (75° C) 30% hydrogen peroxide (H₂O₂) to remove organics (*sensu* LacCore Facility 2007). The sieved (< 1 mm) and pretreated samples underwent laser particle-size analysis at DRI using a Malvern Mastersizer 3000 with Hydro EV.

1.23. Results

1.23.1. Age-Depth Model and Sedimentary Units for Core PAUL-2A

PAUL-2A is a 247-cm long sediment core composed predominately of silt loam, sandy loam, and sand with less frequent layers of gravel, silt, and clay. The final agreement index for the deposition model is $A_{\text{model}} = 93.4$ with an $A_{\text{overall}} = 93.4$, well above the 60% threshold (Bronk Ramsey 1995) that indicates this is a reliable chronological model (Figure 4.6). The model shows two primary periods of deposition in the core. An erosional unconformity is evident at 217-cm depth where poorly sorted gravel overlies an A horizon. Below the unconformity the age depth model shows a decrease in rate of deposition between ~224 to 217 cm depth. The model is nearly linear above the unconformity (~31 yr/cm), except for a slight decrease in rate of deposition between ~95 to 113 cm depth (~45 yr/cm). Core PAUL-2A contains two major sediment packages which I interpret as two lithostratigraphic units (LU) described below, numbered from the bottom-upwards. Particle size, carbon, and nitrogen content are discussed below and presented in Figure 4.7.

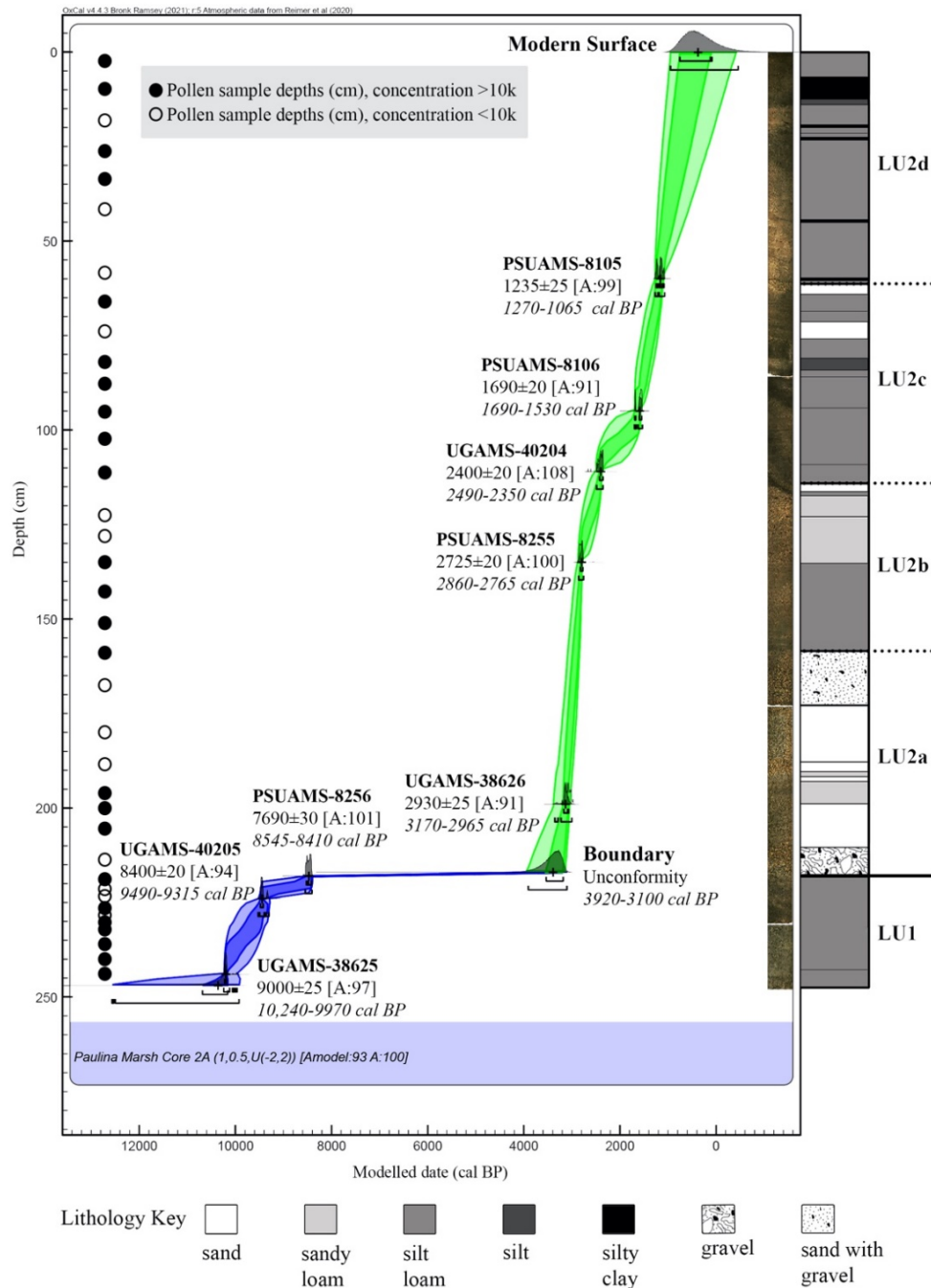


Figure 4.6. Age-depth model output for PAUL-2A generated with a P_Sequence deposition model in OxCal v4.4 (Bronk Ramsey 2008; Bronk Ramsey and Lee 2013) using the IntCal20 radiocarbon calibration curve (Reimer et al. 2020). The light grey probability density functions represent the eight calibrated dates; the dark grey represents the modeled age of each date based on elevation. The light blue and green and dark blue and green are envelopes for interpolated values at 95.4% 68.2% and confidence ranges. Agreement indexes for each date are listed in brackets after the conventional radiocarbon dates. Image from ITRAX core scanner and schematic of major sedimentary units are shown in right columns.

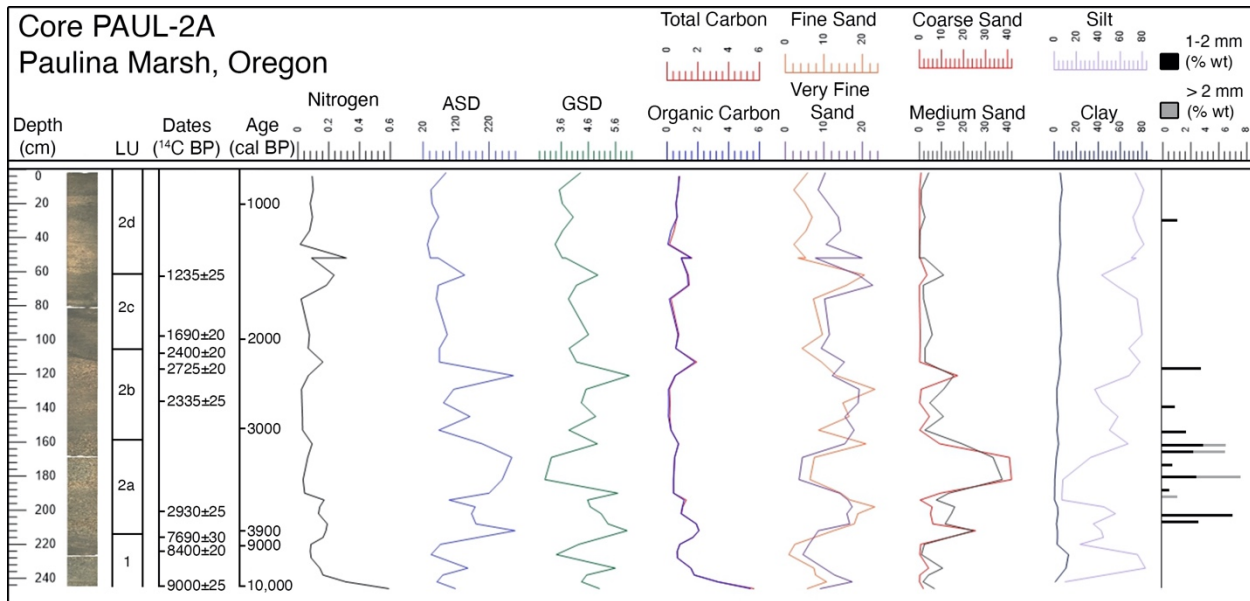


Figure 4.7. Sedimentological and soil characterization data obtained from Core 2A. The far-right column shows the coarse fraction that was removed from samples prior to particle size analysis. No samples from the gravel layer above the unconformity were submitted for particle size or elemental analyses.

LU1 (~10,200-8400 cal BP) is a 30-cm-thick package of pedogenically altered silt loam. At the base of Unit 1 is an incipient buried B horizon composed of a 4-cm-thick layer of very dark grayish brown silt loam with subangular blocky structure, high clay content, and redoximorphic features. This layer had the highest amount of total carbon (5.6%), and very high levels of silt ($\bar{x} = 70.2\%$) and clay ($\bar{x} = 6.5\%$) content relative to the rest of the core. Conformably overlying the B horizon is a 26-cm-thick buried A horizon composed of very dark gray silt loam, strong angular blocky structure, and distinct ped faces. This layer contains relatively high levels of silt ($\bar{x} = 70.9\%$) and clay ($\bar{x} = 8.2\%$). Total carbon content decreased toward the top (3.3% at bottom and 0.83% at top). The A horizon is separated from the underlying incipient B horizon by an abrupt boundary.

An unconformity is present at a depth of 217 cm. This boundary is characterized as a buried erosional surface or disconformity separating the buried A horizon at the top of LU1 and

the moderately subrounded gravel at the base of LU2. Based on the age-depth model, this period of erosion or erosional event occurred sometime between 8400 and 3100 cal BP, more likely after ~3900 cal BP if the gravel at the base of LU2 represents this event.

LU2 (~3900-present) is a 217-cm-thick package containing a conformable sequence of sand, loam, and silt layers with intercalated contacts. This package exhibits upward-fining over the entire 217-cm that is common in alluvium deposited on aggrading point-bars (Waters 1992:130–135). LU2 contains four members based on changes in overall grain size suggesting shifts in depositional energy.

LU2a (~3900 to 2900 cal BP) is a 59-cm-thick member of gravel, sand, and sandy loam layers. At the base of LU2a is a 7-cm thick layer of moderately sorted subrounded gravel that is separated from LU1 by a very abrupt boundary. The age-depth model indicates that sedimentation began sometime between ~3900 and 3100 cal BP (95.4% probability interval). Above the gravel layer, LU2a is composed of alternating layers of dark gray loamy coarse sand (12 cm), brown coarse sandy loam (6 cm), brown coarse sand (1 cm), very dark brown fine sandy loam (1 cm), and brown to very dark gray coarse sand (17 cm). LU2a is capped by a 15-cm-thick layer of grayish brown coarse sand with gravel. LU2a has very low levels of clay (< 3.4%), and the uppermost 20-cm contains the highest levels of total sand (> 90%) of all core samples analyzed for particle size. Total carbon content declines toward the top of the layer (1.67% at bottom and 0.27% at top).

LU2b (~2900 to 2450 cal BP) is a 44-cm-thick member composed of silt loam and sandy loam. From the bottom, there is a 23-cm-thick layer of dark gray silt loam, a 12-cm-thick layer of dark gray fine sandy loam, a 6-cm-thick layer of dark grayish brown sandy loam, a 1-cm lens of black silt loam, and a 2-cm-thick layer of very dark grayish brown loamy coarse sand. Member

LU2b is characterized as having very low total carbon ($\bar{x} = 0.27\%$) and nitrogen ($\bar{x} = 0.04\%$) and decreased sand content relative to LU2a. Member LU2b is separated from LU2a by a clear boundary.

LU2c (~2450 to 1100 cal BP) is a 53-cm-thick member composed primarily of silt loam and silt. At the base is a 30-cm thick layer of silt loam, of which the bottom 20 cm has a higher sand content (~27%) and is lighter in color (gray to dark gray) than the overlying 10 cm, which has ~15% or less sand and ranges from very dark gray to black. Above this is 20 cm of alternating dark gray silt (3 cm), black silt loam (5 cm), dark gray brownish sand (4 cm), dark gray to very dark gray silt loam (8 cm), and dark grayish brown sand (3 cm). Average total carbon is higher ($\bar{x} = 1.04\%$) relative to LU2b and LU2d, with carbon level increasing toward the top. Member LU2c is separated from LU2b by a very abrupt boundary.

LU2d (~1100 cal BP to modern surface) is a 61-cm-thick member composed of silt loam, silt, and clay. The bottom 49 cm consist of dark gray to very silt loam containing four thin (< 1-cm-thick) black silt lenses. The bottom 40 cm of silt loam is very dark gray, and the upper 7 cm is dark gray. Overlaying the silt loam is a 2-cm-thick layer of very dark gray silt, followed by 6-cm-thick layer of silt clay with some roots and 6-cm-thick-layer of biologically active silt loam with abundant roots. Total carbon ($\bar{x} = 0.72\%$) and nitrogen ($\bar{x} = 0.11\%$) percentages are generally low, with the highest values occurring in the lowest 10 cm. Unit LU2d is separated from LU2c by an abrupt boundary, and its uppermost 12 cm represent the modern surface layer and root zone.

1.23.2. Palynological Record

The pollen assemblage from PAUL-2A demonstrates temporal variability in marsh vegetation, as well as variation in levels of pollen preservation throughout the core (Figures 4.8

and 4.9). This includes the identification of 47 plant taxa from 34 families (Appendix D). Figures 4.10 and 4.11 provide examples of identified pollen taxa. Frequency of degraded pollen ranged from zero to 22%, and PCV ranged from zero to 303,788 grains per cc. I excluded 16 samples from the pollen diagram in Figure 4.8 because they either had no preserved pollen ($n = 4$; P15, P18, P20, P26), had PCVs lower than 10,000 ($n = 11$; P4, P5, P8, P13, P17, P25, P32, P33, P34, P36, P39), or were taken from within a section of the core identified as infilling ($n = 1$; P10). Pollen zones identified by the CONISS cluster analysis are not statistically significant according to the broken stick model. Though not statistically significant, two major pollen zones are evident: Buck-1 and Buck-2 located below and above the unconformity, respectively. Further, Buck-2 can be divided into two subzones at a location consistent with the ordination analysis (though not significant at $p < 0.05$).

Buck-1 (247-217 cm depth, ca. 10,200-8400 cal BP) is characterized by increasing average Cyperaceae percentages (0-30.2%), maximum levels of broadleaf cattail (*Typha latifolia*) ($\bar{x} = 1.7\%$; maximum = 5.3%), and absence of Cupressaceae pollen. Nearly all arboreal pollen comes from pine (*Pinus* spp.) ($\bar{x} = 22\%$), with low frequencies of alder (*Alnus* sp.) and negligible amounts of fir (*Abies* sp.) and birch (*Betula* sp.) ($\bar{x} = < 0.1\%$). Average percentages of *Artemisia* (1.4% at bottom and 0% at top) and amaranth family (Amaranthaceae) (2.4% at bottom and 0.4% at top) decrease toward the top of this zone. Samples from Buck-1 have a low average PCV (31,695). One sample from this zone has zero preserved pollen and three have a PCV under 10,000.

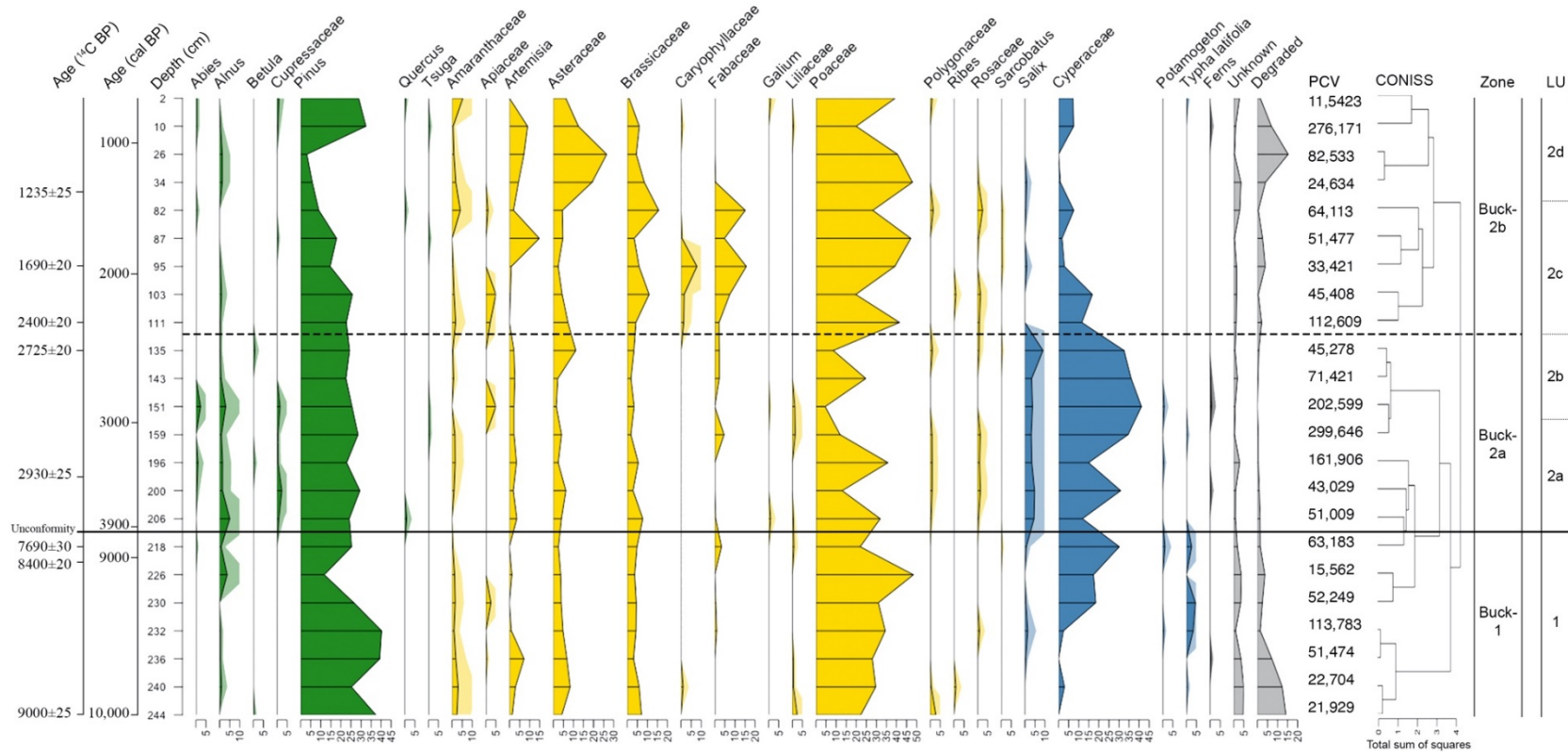


Figure 4.8. Pollen percentage diagram for PAUL-2A showing selected pollen taxa, pollen concentration values (PCV), pollen zones, and lithostratigraphic units. Lighter colored shading indicates 5x exaggeration of pollen percentages. Taxa are organized by arboreal (green), herbs and shrubs (yellow), and aquatic/riparian (blue). Only pollen samples with PCV greater than 10,000 are included in this diagram.

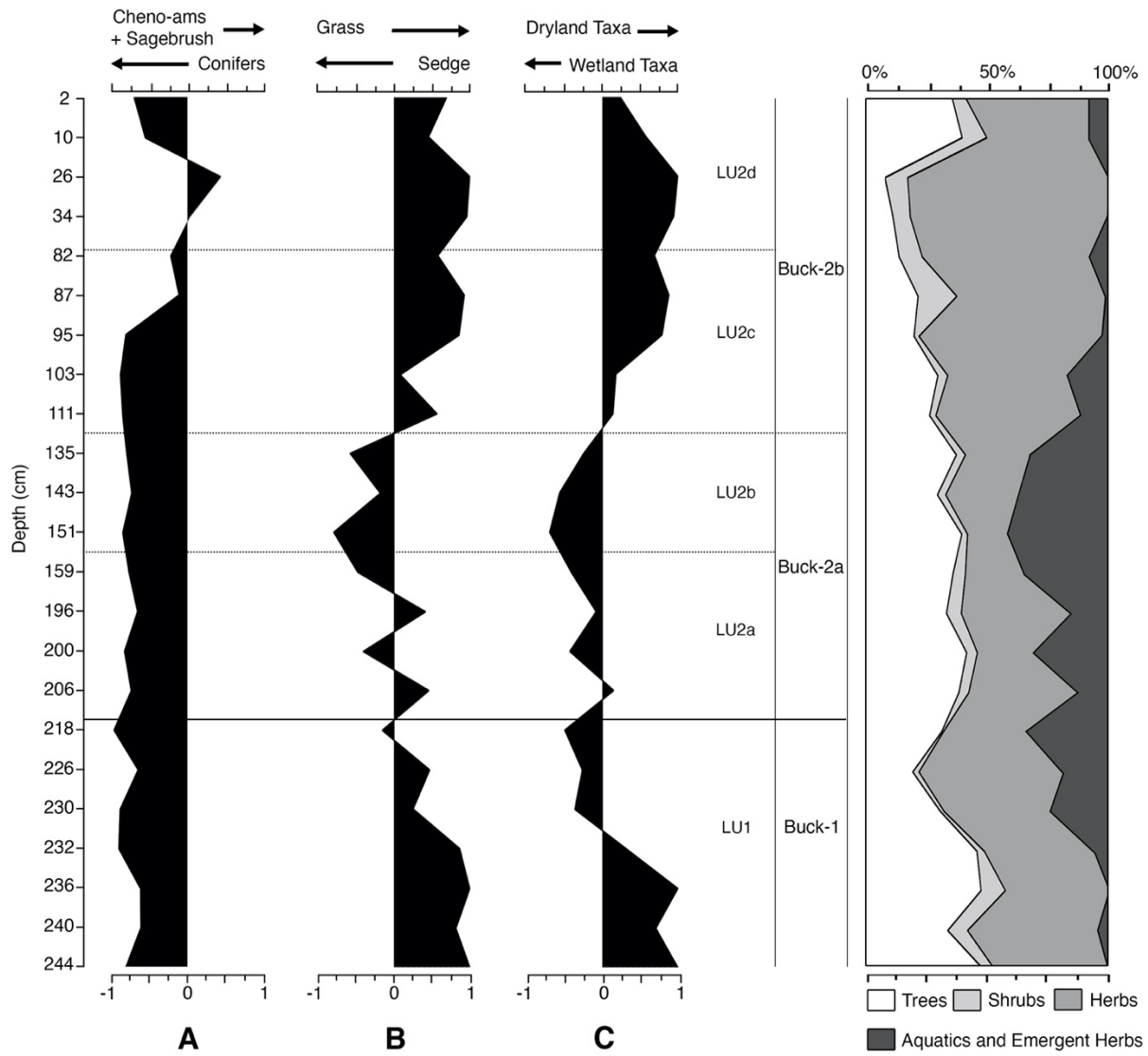


Figure 4.9. Ratio of pollen abundance between taxa. Ratios between types are calculated as $(\text{Type 1} - \text{Type 2}) / (\text{Type 1} + \text{Type 2})$. (A) cheno-ams (all *Amaranthaceae*) vs. sagebrush (*Artemisia*); (B) grass family (*Poaceae*) vs. sedge family (*Cyperaceae*); (C) dryland taxa (*Amaranthaceae*, *Artemisia*, *Asteraceae*, *Brassicaceae*, *Fabaceae*) vs. wetland taxa (*Cyperaceae*, *Potamogeton*, *Sagittaria*, *Typha latifolia*).

Buck-2 consists of all deposits above the unconformity. Buck-2a (217-114 cm depth, ca. 3900 to 2450 cal BP) is characterized by increased and maximum percentages of *Cyperaceae* ($\bar{x} = 20.9\%$; maximum = 41.2%) and *Salix* ($\bar{x} = 3.4\%$; maximum = 9%). *Pinus* remains steady at an average of 22.41%, with slight increases in other arboreal pollen including *Abies* ($\bar{x} = 0.3\%$) and

Alnus ($\bar{x} = 2.4\%$). Percentages of Poaceae are much lower in this zone ($\bar{x} = 22.1\%$) relative to other times ($\bar{x} = 44.4\%$ in Buck-1; $\bar{x} = 38.3\%$ in Buck-2b). Buck-2a marks the first appearance of Cupressaceae in the record, occurring in four samples ($\bar{x} = 0.5\%$; maximum = 2.4%). This zone has the highest average PCV (70,213) and lowest levels of degraded pollen ($\bar{x} = 1.6\%$) in the core. Three samples from this zone have zero preserved pollen, and two samples have a PCV under 10,000.

In Buck-2b (114-0 cm depth, ca. 2450 cal BP to surface) wetland and arboreal taxa decrease while terrestrial shrubs and herbs reach their maxima. *Salix* ($\bar{x} = 0.6\%$), Cyperaceae ($\bar{x} = 2.3\%$), and *Typha* ($\bar{x} = 0.2\%$) all decline, as do arboreal taxa including *Pinus* ($\bar{x} = 11.7\%$), *Alnus* ($\bar{x} = 0.7\%$), Cupressaceae ($\bar{x} = 0.5\%$), and *Abies* ($\bar{x} = 0.1\%$). *Betula* disappears completely. *Artemisia* ($\bar{x} = 7.2\%$; maximum = 25%), other Asteraceae ($\bar{x} = 11.6\%$; maximum = 26.6%), mustard family (Brassicaceae) ($\bar{x} = 9.5\%$; maximum = 32.5%), and legume family (Fabaceae) ($\bar{x} = 4.5\%$; maximum = 21.4%) increase. Samples in this zone have an average PCV of 56,469 and high levels of degraded pollen ($\bar{x} = 5.9\%$). Five samples have PCVs under 10,000.

1.23.3. Initial Radiocarbon Dating of Other Cores

Four of the samples submitted from cores other than PAUL-2A returned radiocarbon ages, while six failed due to inadequate organic content. Three of the four samples from PAUL-2B were successfully dated and roughly correspond stratigraphically (and elevationally below the surface) to similar ages obtained from PAUL-2A; however, in PAUL-2B there is no layer of Mount Mazama tephra and only 116 cm of sediment separates an age of 1345 ± 15 ^{14}C BP (1345-1295 cal BP) and 8010 ± 35 ^{14}C BP (9010-8720 cal BP)—all suggesting that the unconformity observed in PAUL-2A is also present in PAUL-2B.

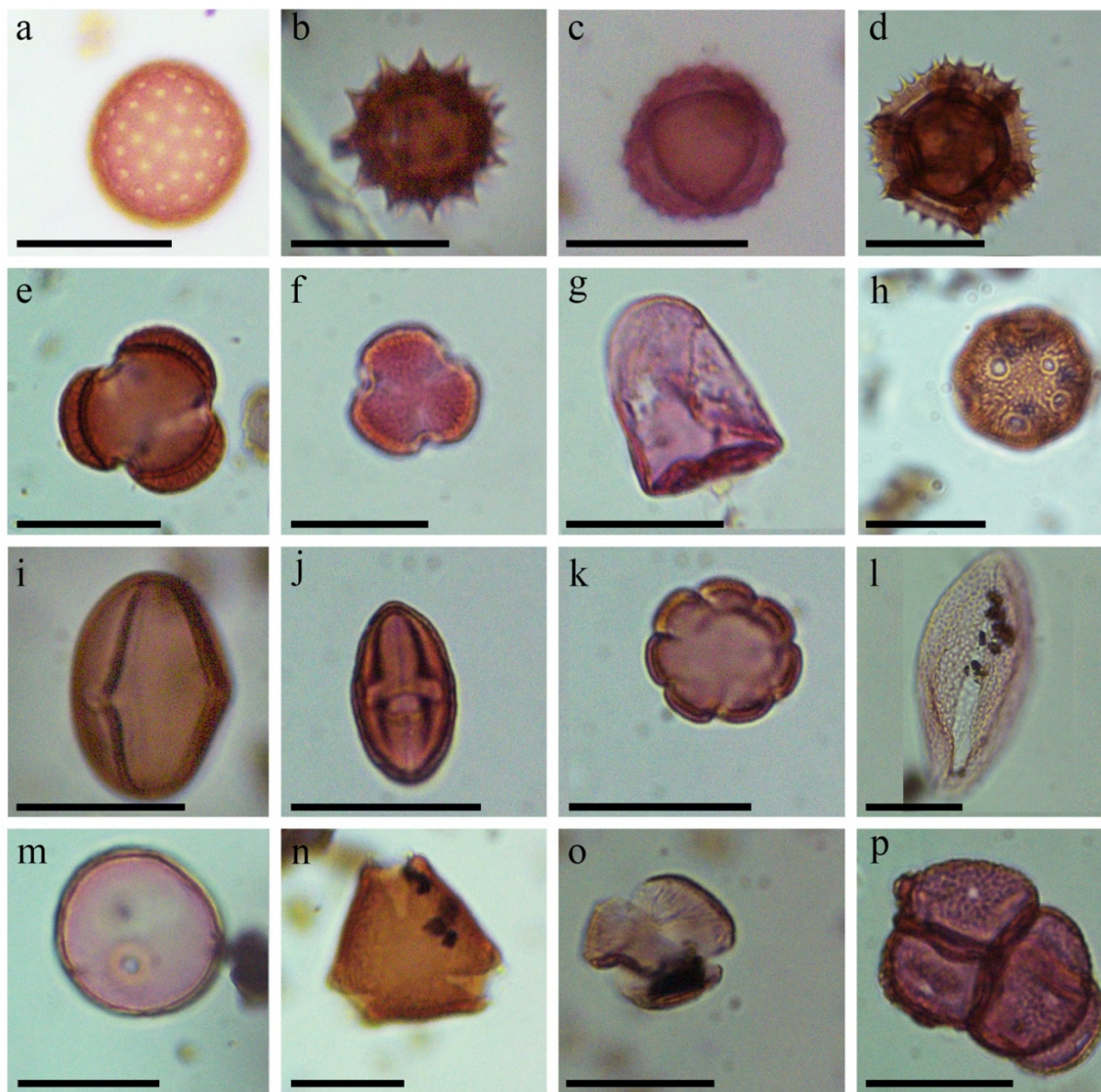


Figure 4.10. Examples of herbaceous shrubs and grass pollen identified in PAUL-2A: (a) Amaranthaceae; (b) Asteraceae, high-spine; (c) Asteraceae, ragweed-type; (d) Asteraceae, dandelion-type; (e) *Artemisia* spp.; (f) Brassicaceae; (g) Cyperaceae; (h) Caryophyllaceae; (i, j) Fabaceae; (k) *Gallium*; (l) Liliaceae; (m) Poaceae; (n) Rhamnaceae; (o) Rosaceae; (p) *Typha latifolia*. Scale bars are 25 microns.

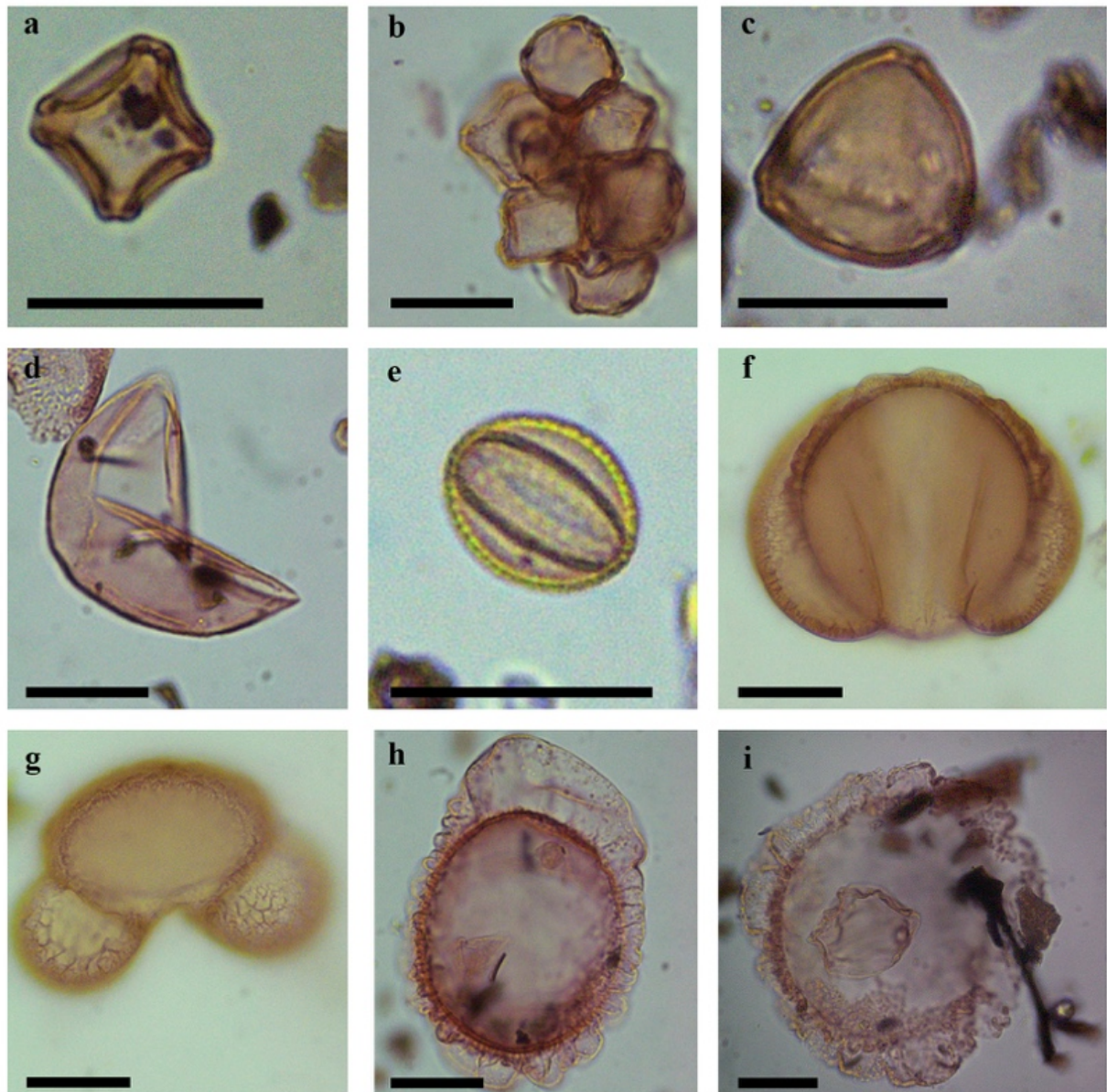


Figure 4.11. Examples of arboreal pollen identified in PAUL-2A: (a) *Alnus*; (b) *Alnus* aggregate; (c) *Betula*; (d) Cupressaceae; (e) *Salix*; (f) *Abies*; (g) *Pinus*; (h-i) *Tsuga*. Scale bars are 25 microns.

A bulk sample from the base of PAUL-2B could not be dated due to lack of organic material, and the lower ~180 cm of the core remains undated, except that it must be older than ~10,500 cal yr BP, given the lowermost age of 10,680-10,240 cal yr BP from 407-409 cm. A bulk sediment sample from the base of PAUL-6 returned a radiocarbon date of 6690 ± 30 ^{14}C BP (7615-7485

cal BP). This age suggests that PAUL-6 may contain sediment of Middle Holocene age that was not captured in cores PAUL-2A and PAUL-2B. I have not attempted to radiocarbon date PAUL-C. All five samples submitted from PAUL-72H failed to return radiocarbon ages due to lack of carbon.

Radiocarbon dating results for these cores indicate sediment packages of variable ages are present in different locations of the marsh and supports the need for obtaining samples from multiple areas, especially the more reliably saturated zones in the southwest. The lack of carbon over long lengths of PAUL-7H2 indicates highly oxidative conditions in the northern marsh, possibly due to repeated drying. These results are consistent with fieldwork by Benjamin (1994), who reported variability in the geomorphic character of the marsh and noted that the northern marsh was the first area to retract during xeric periods.

1.24. Interpretations and Discussion

The geomorphological and palynological data from PAUL-2A provide a first look at the hydrologic and vegetation histories of Paulina Marsh. Due to variability in pollen preservation, depositional environment, and sample increments, the record of PAUL-2A is most suitable for examining broad changes at a multi-century scale. Processes of alluvial deposition and erosion at the PAUL-2A core site reflect variable levels of water energy as the area flooded and drainage streams meandered. Overall, shifts in depositional environment correspond well with changes in the pollen record. Radiocarbon ages from other core sites further demonstrate the variability in depositional processes throughout Paulina Marsh and highlight areas where complementary records might be obtained in the future.

1.24.1. Geomorphological History

Core PAUL-2A is composed of an Early Holocene sediment package (LU1) reflecting a period of landform stability. Pedogenesis below 231-cm-depth documents a period of subaerial soil formation at the core site, and redoximorphic features in the B horizon indicate wetting and drying sometime after pedogenesis occurred, as soil formation processes would have destroyed such features. Poor pollen preservation in the lower ~15 cm of LU1 is consistent with wet-dry cycles, which are damaging to pollen grains (Bryant 1989; Campbell and Campbell 1994; Holloway 1989).

Unconformably overlying LU1 is a Late Holocene sediment package (LU2) that exhibits a fining-upward sequence. The gravel at the base of LU2 is consistent with a channel lag environment and suggests that a meandering stream flowed over the core site, removing any Middle Holocene deposits that may have accumulated, including Mazama tephra, and possibly truncating the A horizon of LU1. More sediment cores are needed to test for the presence of Middle Holocene deposits elsewhere in the Buck Creek floodplain and to investigate whether the A horizon represented in LU1 is thicker in other areas. A radiocarbon date from the base of PAUL-6 suggests that deposits dating to the Middle Holocene are preserved toward the central marsh.

Geomorphology of LU2 is consistent with a fining-upward fluvial sequence of a point bar (Waters 1992:130–135). Lidar imagery (Figure 4.3) appears to show a partially buried channel ~15 m east of the core site. The channel is ~2 m wide and is now ~0.5 m deep. All radiocarbon ages obtained above the gravel layer at the base of LU2a date to the Late Holocene, and the age-depth model indicates that the erosional event marking the top of LU1 happened sometime before 3900 cal BP. Coarse-grained deposits in LU2a are consistent with channel-margin

sediments, suggesting that the core site remained within or very near the stream channel for at least ~1000 years following the unconformity. A transition from coarse-grained to fine-grained sediments starting in LU2c indicates a decrease in depositional energy beginning around 2500 cal BP. The fine-grained deposits of LU2c suggest that the core site was no longer proximal to the stream channel. Silt loam deposits with thin layers of sand that comprise LU2c indicate alluvial deposition with intermittent pulses of stronger and lower water flow. A possible explanation for this shift is that the main channel may have switched to the channel located ~55 m west of the core site and away from the buried channel that runs by the core site (Figure 4.3). The silt loam deposits with interspersed black silt lenses and clay that comprise LU2d were likely derived from a low energy, quiet water environment where very fine silts and organics accumulated during the last ~1100 calendar years.

1.24.2. Taphonomy of Pollen Record

Geomorphic setting and depositional environment are important to consider when reconstructing past vegetation from pollen in alluvial contexts. Lake sediments are the preferred setting for pollen analysis because they often have uninterrupted stratigraphy, good pollen preservation, and macrobotanical remains that can be radiocarbon dated; however, reworking and pollen sorting can also occur in lake environments (e.g., Davis and Brubaker 1973; Davis et al. 1984; Tian et al. 2008). Nearly all pollen records are affected to some degree by issues of pollen preservation (Xu et al. 2016:154) stemming from characteristics of the pollen grain (e.g., amount of sporopollenin, exine characteristics and thickness) or environmental factors (e.g., oxidation, microbial activity). My placement of PAUL-2A in the southwestern marsh was intended to avoid areas where cycles of wetting and drying were likely to have caused significant breakage and corrosion of pollen grains (e.g., the northern and northeastern marsh) (Campbell

and Campbell 1994; Holloway 1989), but this location introduced issues relating to pollen from alluvial settings. Fall (1987) warns that pollen from alluvial settings is unreliable for reconstructing past vegetation due to issues of sorting and reworking during water transport. Other researchers (e.g., Hall 1989; Xu et al. 1996, 2016) contend that such reconstructions are possible, pointing out that similar processes occur in many sedimentary contexts, and the effects of pollen sorting in river water is typically minimal. A benefit of alluvial deposits in marshes like Paulina is that water energy is low, and the catchment area is small relative to rivers or large lakes, and should therefore reflect local vegetation. Sediment cores from Paulina Marsh are also critical sources of data because no lakes persist in the Fort Rock Basin today, and lake cores from neighboring basins have been unable to capture the terminal Pleistocene or Holocene data due to hiatuses or disconformities in the sedimentary records (Cohen et al. 2000; Negrini et al. 2000).

In the Buck Creek floodplain, pollen sources include an aerial component (e.g., pollen rain) and an alluvial component from stream flow, flooding, and sheet-wash events. Therefore, the PAUL-2A pollen assemblage could contain waterborne pollen transported from the foothills of Yamsay Mountain in addition to pollen from vegetation in the immediate vicinity, and possibly reworked sediment during times of higher water energy, such as the base of LU2. There is a slight increase in some arboreal pollen at the base of LU2, potentially indicating increased representation of pollen from upstream; however, the level of *Pinus* remains constant throughout the gradual change in water energy, and Cyperaceae, which is generally limited to lowland meadow or marsh settings, increases, suggesting that local vegetation is still represented in the pollen spectrum even when water energy increased. Stream channels near the PAUL-2A core site are relatively small, ranging from ~1.5 to 2.5 m in width and ~0.5 m in depth (though infilling

may have obscured the original depths in the now non-active channels). Water flowing through such channels would be capable of transporting pollen and possibly size sorting pollen or redepositing pollen from older alluvial deposits. Still, such processes in the low energy of Buck Creek would be less extreme relative to meandering rivers. The initial paleoecological interpretations of PAUL-2A are discussed here with the caveat that various environmental, depositional, and taphonomic variables may be affecting the pollen record.

1.24.3. Vegetation History

The PAUL-2A record reveals broad changes in vegetation of the southwestern marsh. High levels of pollen degradation in the lower half of the Buck-1 zone complicates interpretation. It is possible that the low levels of Cyperaceae, which have fragile pollen grains, could be related to poor pollen preservation; however, low levels of emergent and aquatic taxa correspond with higher levels of terrestrial shrubs and herbs, suggesting that the core site may have been drier before ~9000 cal BP. The presence of *Typha latifolia* and pondweed (*Potamogeton*) toward the top of the Buck-1 zone suggest that the southwestern marsh held enough standing water to support emergent marsh vegetation between ~9000 and 8400 cal BP. The relatively high ubiquity of *Typha* in the upper ~15 cm of Buck-1 is notable, as pollen of this species is nearly absent in the other pollen zones. *Typha latifolia* is an obligate wetland indicator species tolerant of continuous or seasonal flooding and moderate salinity (Stevens and Hoag 2006), though it is typically restricted to water depths less than 64 cm (Baldwin and Cannon 2007). This suggests there was an area of shallow, slow moving, or still water near the core site during the latter part of the Early Holocene. Cyperaceae also increases within the upper 15 cm of Buck-1, which could signal the development of a sedge meadow or wetland within or near the Buck Creek floodplain.

Cupressaceae pollen is notably absent from the Early Holocene samples, due to either sampling/taphonomy or its actual absence from the landscape at that time. Cupressaceae appears, albeit in low amounts, throughout the Buck-2a and Buck-2b zones, suggesting that *Juniperus* was growing in the area by at least ~3900 cal BP and continued to be locally present until modern times. The frequency of Cupressaceae pollen never exceeds 3% and is also low in the modern surface sample (~1%), despite a *Juniperus occidentalis* tree growing within 100 m of the core site. Studies examining modern surface samples in the Great Basin have reported similarly low frequencies of Cupressaceae. For example, modern samples analyzed by Beck and colleagues (2018) found ~5% Cupressaceae when *Juniperus occidentalis* trees were present at the collection site and ~3% when the trees were within 1 km. Similarly, Minckley and colleagues (2008) report ~9% Cupressaceae in pinyon/juniper (*Pinus monophylla*/*Juniperus*) woodlands and ~2% in *Artemisia* steppe. Pollen analysis of sediment cores from Diamond Pond in Diamond Craters, Oregon, found between 3% and 6% Cupressaceae pollen in sections of the core with low numbers of *Juniperus* seeds and up to 9% in sections with high numbers of seeds (Mehring and Wigand 1987; Wigand 1987). Low levels of Cupressaceae in the PAUL-2A record could also be explained by the fragility of these pollen grains, which easily rupture when in contact with water and become rapidly unrecognizable with subsequent degradation accelerated by wet/dry cycles (Beck et al. 2018; Ciani et al. 2021). While pollen preservation may be an issue, some of the Early Holocene samples have comparable preservation and PCV to those which contained Cupressaceae in the Late Holocene samples.

The alternative explanation for the absence of Cupressaceae in the Early Holocene samples is that *Juniperus occidentalis* was not yet growing along the edges of the basin as it does today. Northward expansion of *J. occidentalis* around the time of the Pleistocene to Holocene

transition, possibly in response to warming temperatures, is a matter of study, and it is currently unclear when this species became established in the Fort Rock Basin (Mehring and Wigand 1987; Miller et al. 2005). Wigand and Rhode (2002:221-223; also see Mehring and Wigand 1987) discuss the northward expansion of *Juniperus* by at least ~8500 cal BP, as shown in the pollen records from Bicycle Pond on Hart Mountain in the Warner Valley of Oregon and from McCoy Flat in northern California. The earliest identification of *Juniperus* in the Fort Rock Basin is charcoal from Component 1 (ca. 10,000-8500 cal BP) at the Locality III archaeological site, but those charcoal samples were not directly dated (Jenkins, Droz, et al. 2004; Prouty 2004). All other identifications are from substantially younger contexts, including a *Juniperus* berry in a Middle Holocene (~5600-4500 cal BP) feature at DJ Ranch (Moessner 2004); *Juniperus* charcoal in Structure 1 (4880 ± 110 ^{14}C BP; 5890-5330 cal BP) at the Big M site (Jenkins 1994; Stenholm 1994); *Juniperus* seeds from a coprolite (3315 ± 35 ^{14}C BP; 3635-3450 cal BP) at Connley Caves (McDonough 2019; Chapter III); and low levels (< 1%) of Cupressaceae pollen in samples below a bulk age of 6470 ± 70 ^{14}C BP (7560-7260 cal BP) in a sediment column from Silver Lake (Cummings 2001). Together, these data confirm that *Juniperus* was established in the Fort Rock Basin by the Middle Holocene, but possibly not during the Early Holocene. This is surprising given that Cupressaceae pollen is evident in pollen cores at Paisley Caves in the neighboring Chewaucan Basin by at least ~14,000 cal BP (Beck et al. 2018; Saban 2015). Continued analysis of macrofossils from early archaeological sites as well as fossil pollen from additional sediment cores at Paulina Marsh could help refine our understanding of the local history of *Juniperus occidentalis*.

In the Buck-2a zone (ca. 3900 to 2450 cal BP), the presence of *Potamogeton* and increasing frequency of Cyperaceae suggests that the Buck Creek floodplain was well watered,

and the ubiquity of *Salix* and *Alnus* is indicative of a nearby stream. This is consistent geomorphologically, that the core site was within a stream channel as a point bar developed. The pollen profile suggests that a Cyperaceae marsh developed in or near the Buck Creek floodplain sometime between ~2930 and 2800 cal BP. Poaceae reaches its lowest frequencies in Buck-2a, which is also consistent with constant inundation of the core site. More ubiquitous, albeit in low levels, is *Abies*, *Alnus*, and *Betula*, which likely originated in the foothills of Yamsay Mountain and may reflect a slight downslope shift of these taxa; however, this could also be related to the depositional environment with higher energy streamflow transporting pollen from further upslope to the core site.

A sharp drop in Cyperaceae, near disappearance of *Salix*, and declines in *Pinus* and *Alnus* in the Buck-2b zone indicate drier conditions near the core site beginning ~2200-2000 cal BP. Drier conditions are also consistent with decreased water energy indicated by the geomorphology of LU2c and LU2d. By ~1600 cal BP, rising levels of Poaceae, *Artemisia*, other Asteraceae, Fabaceae, and Brassicaceae, as well as a slight increase in Amaranthaceae suggest the expansion of xeric *Artemisia* steppe near the Buck Creek floodplain. This pattern coincides with a decline in aquatic and riparian taxa indicative of marsh contraction. *Typha latifolia* and *Potamogeton* are absent from the Buck-2b zone until ~500 cal BP. Increased frequency of *Pinus* in the uppermost samples potentially indicates forest expansion within the last ~500 years.

To summarize, PAUL-2A contains pollen sequences dating to the Early and Late Holocene that can be subdivided into three primary pollen zones: Buck-1, Buck-2a, and Buck-2b. Buck-1 shows that between ~9000 and 8400 cal BP there was landform stability and pedogenesis at the core site, and the marsh contained enough water to support emergent plant communities. The lack of Cupressaceae pollen at this time presents the possibility that *Juniperus*

occidentalis was not yet established in the immediate area. During the Late Holocene, increasing frequency of Cyperaceae in Buck-2a suggests the presence of a wet meadow or marsh with standing water, at least intermittently, between ~3900 to 2500 cal BP. A sharp decline of wetland taxa in Buck-2b suggests a transition to drier conditions ~2200-2000 cal BP. Wetland versus dryland ratios remain high for the next 2000 years; however, increases in *Pinus*, Cyperaceae, and the reappearance of *Typha latifolia* ~500 years ago may signal more mesic conditions.

1.24.4. Comparison to Other Pollen Records

Comparison of data from this study with other pollen records from the northern Great Basin shows that vegetation shifts observed in PAUL-2A generally correspond with regional trends (Figures 4.12 and 4.13). This correspondence also suggests that alluvial redeposition is not the primary source of pollen in LU2. Here I consider pollen spectra from Diamond Pond (1265 m; Wigand 1987), Bicycle Pond (1800 m; Wigand and Rhode 2002), Fish Lake (2250 m; Mehringer 1985); Wildhorse Lake (2565 m; Mehringer 1985), Dead Horse Lake (2248 m; Minckley et al. 2007), Paisley Caves (1370 m; Beck et al. 2018; Saban 2015) and Craddock Meadow (1630 m; Wigand 1989) in Oregon, and Lily Lake (2042 m; Minckley et al. 2007) in California (Figure 4.12).

During the Early Holocene, regional vegetation histories generally indicate warmer and drier conditions between ~11,000 and 9000 cal BP relative to earlier times (Beck et al. 2018; Mehringer 1986; Minckley et al. 2007). Pollen records at Paisley Caves indicate more xeric conditions during the Early Holocene relative to the Younger Dryas and possible upward retreat of forests ca. 10,700 cal BP (Beck et al. 2018; Saban 2015). At Fish Lake, *Artemisia* grassland expanded upslope into previous alpine grassland between ~10,000 and 9000 cal BP (Mehringer 1985, 1986). Those records are indicative of warming climate conditions; however, it may have

still been relatively wet compared to modern times. For example, high frequencies of Poaceae and Cyperaceae at Diamond Pond suggest a more extensive marshland during the Early Holocene relative to now (Wigand and Rhode 2002). Climatic reconstructions at Lily and Dead Horse lakes indicate lower moisture availability between 12,500 and 9000 cal BP, followed by lower temperatures and increased moisture after 9000 cal BP (Minckley et al. 2007). This fits with Mehringer's (1986) proposal of increased summer rainfall between ~10,000 and 8000 cal BP. Dry conditions are also indicated in the Buck Creek floodplain, where the ratio of dryland to wetland taxa is at its maximum between ~10,000 and 9500 cal BP (Figure 4.9). Increasing wetland taxa and appearance of *Typha latifolia* in the upper levels of the Buck-1 zone suggest wetter conditions after ~9500 cal BP.

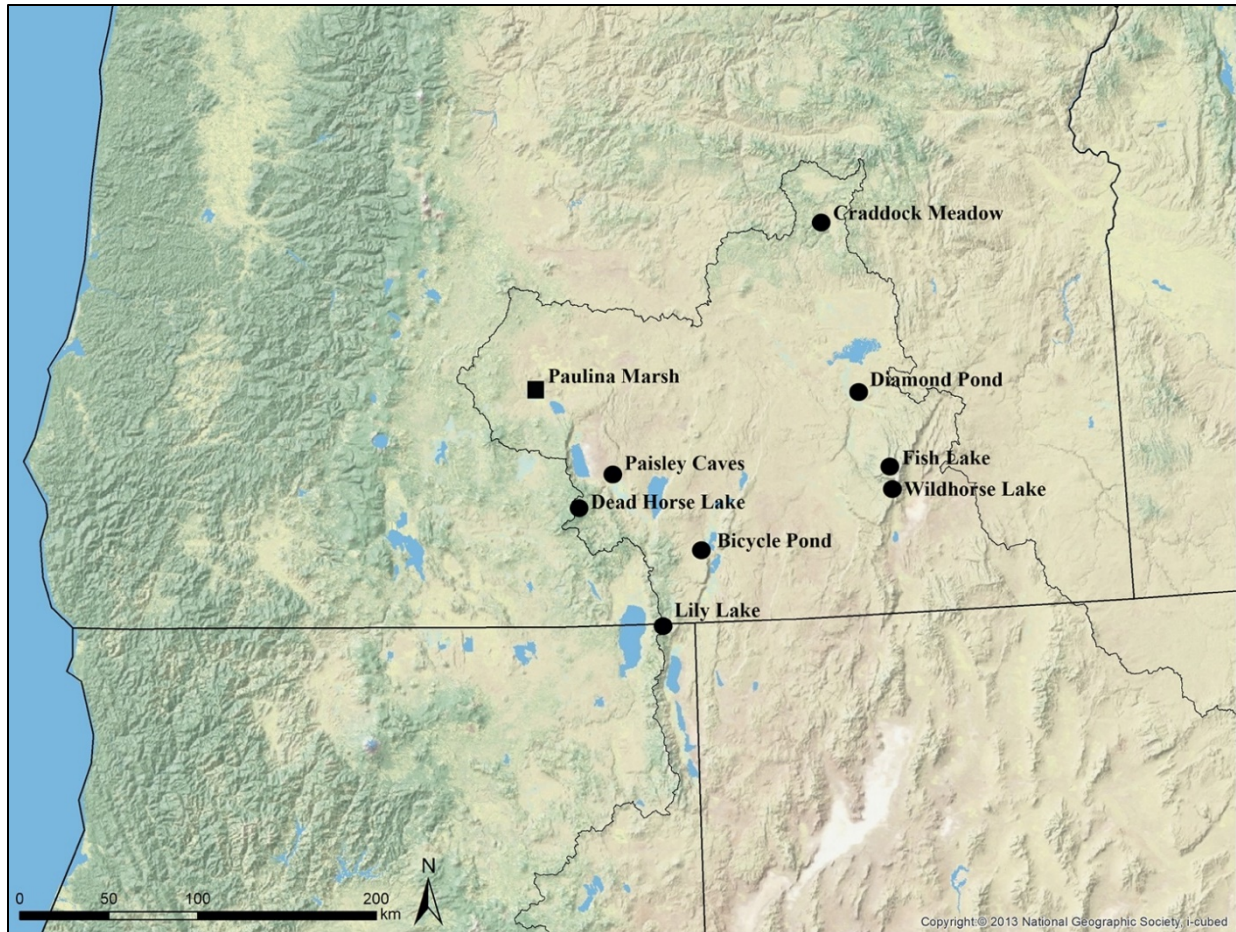


Figure 4.12. Locations of pollen cores and profiles discussed in the text shown within an outline of the northern Great Basin.

The Middle Holocene encompasses both the driest and wettest periods in Holocene paleoenvironmental records of the northern Great Basin. Prolonged drought conditions between ~8000 and 6000 cal BP caused widespread desiccation of water bodies (Aikens et al. 2011; Wriston 2009), and all pollen records spanning this time reflect an upslope shift in vegetation indicative of xeric conditions. Examples include saltbush (*Atriplex* sp.) scrub and *Juniperus* encroachment into *Artemisia* grasslands at Bicycle Pond (Wigand and Rhode 2002), movement of *Artemisia* grassland upward into alpine grassland at Wildhorse Lake (Mehringer 1985), and *Abies concolor* expansion upslope in the Warner Mountains (Minckley et al. 2007). Interruptions

in woodrat midden records suggest that rodents were also affected by climate change (Jennings and Elliot-Fisk 1993; Wigand and Nowak 1992). Ameliorating conditions beginning around 6000 cal BP prompted the resurgence and bolstered productivity of marshes and lakes throughout the northern Great Basin (Aikens et al. 2011; Minckley et al. 2004, 2007; Wigand and Rhode 2002). Lowland pollen records show *Artemisia* communities replacing *Atriplex* scrub that dominated during the previous drought period (Mehring 1985; Minckley et al. 2004; Wigand 1987). In the Fort Rock Basin and neighboring areas, significant sand dune formation occurred during this time, following the desiccation of valley floors (Dugas 1998; Mehringer and Cannon 1994; Mehringer and Wigand 1986). The unconformity in PAUL-2A suggests that water levels were very low some time during the Middle Holocene, prior to 3900 cal BP, as the stream that flowed over the core site had erosive power. The lack of a Middle Holocene record in PAUL-2A could be due to a combination of reduced alluviation in the Buck Creek floodplain during the period of exceptional aridity at the onset of the Middle Holocene, followed by amplified stream flow with more mesic conditions during the late Middle Holocene.

Climatic indicators throughout the northern Great Basin signal cooler and wetter conditions between 4000 and 2000 cal BP, relative to later times (Wigand and Rhode 2002). The pollen and macrofossil records from Diamond Pond (Wigand 1987) and packrat middens at Diamond Craters (Mehring 1990) indicate expansion of *Juniperus* woodland into lower elevations beginning around 4500 cal BP, with simultaneous and subsequent bursts of forest and woodland expansion there and elsewhere in the northern Great Basin ~3700, 2700, and 2300 cal BP (Wigand 1989; Wigand and Rhode 2002). A return to alpine grassland from sagebrush grassland at Wildhorse Lake ~4000 cal BP similarly signals wetter and possibly cooler conditions (Mehring 1985). An exceptionally wet period at Diamond Pond (Wigand 1987) ca.

4000 cal BP is roughly coeval with the last possible time for the event that caused the erosional unconformity in PAUL-2A. The development of a Cyperaceae meadow or marshland at the Buck Creek floodplain between ~2900 and 2450 cal BP fits within an interval of extensive marshland at Diamond Pond, between ~2800 and 2050 cal BP (Wigand 1987). The brief ~50-year-drought around 2950 cal BP indicated in the Diamond Pond record is not apparent in PAUL-2A, which could be an issue of coarse sampling in the latter.

Regional vegetation records indicate warmer and drier conditions beginning ~2000 cal BP (Wigand 1987; Wigand and Nowak 1992; Wigand and Rhode 2002). Declines in aquatic plant macrofossils, *Juniperus*, and Poaceae pollen at Diamond Pond show a drop in water level ca. 2050 cal BP. Around the same time, the pollen record at Fish Lake shows decreased Poaceae and increased *Artemisia* indicative of drier conditions (Mehring 1987). These regional trends of warming and drying ca. 2000 cal BP generally correspond to increases in terrestrial pollen and rising levels of *Artemisia* in the Buck-2b zone of PAUL-2A. Multiple lines of data, including elevated Poaceae ratios in multiple pollen records (Wigand 1987, 1997; Wigand and Rhode 2002) and dramatic increase in bison (*Bison* spp.), indicate significant Poaceae expansion throughout the northern Great Basin between 1900 and 1000 years ago (Grayson 2006). This timing corresponds with increased frequencies of Poaceae and declining *Pinus* and Cyperaceae in PAUL-2A.

1.24.5. Comparison to Human Palaeoecological Models in the Fort Rock Basin

Some archaeologists contend that cultural phases or patterns of human settlement-subsistence in the northern Great Basin were heavily influenced by changes in effective moisture and productivity of marsh habitats (Aikens and Jenkins 1994; Aikens et al. 2011; Jenkins 1994; Jenkins et al. 2004). Both archaeological and ethnographic data highlight the vital role of marsh

and lacustrine resources to the lifeways of Indigenous groups of the northern Great Basin (Aikens et al. 2011; Coville 1897; Fowler 1986, 1992; Jenkins et al. 2004; Ray 1963; Spier 1930). Here I consider how data from Paulina Marsh corresponds with and stands to contribute to this understanding of cultural phases in the Fort Rock Basin (Figure 4.13).

The Fort Rock Period (ca. 12,000 to 9000 cal BP) is characterized by residential use of caves positioned along the edges of receding lakes (e.g., Connley Caves [Bedwell 1970, 1973; Jenkins et al. 2017], Cougar Mountain Cave [Rosencrance et al. 2019], and Fort Rock Cave [Connolly et al. 2017]) with seasonal use of the uplands (e.g., Paulina Lake [Connolly and Jenkins 1999]) and early evidence for cooperative mass-hunting in the lowlands (e.g., Buffalo Flat [Oetting 1994]) (Jenkins et al. 2004). Overall, archaeological assemblages from this time indicate seasonal sedentism and broad-spectrum foraging (Jenkins et al. 2004). Human occupations at Connley Caves were most substantial and frequent during the Younger Dryas (ca. 12,900 to 11,700 cal BP), waning substantially at the Holocene onset (Rosencrance 2019; Chapter III). Declining use of Connley Caves corresponds to the basal samples of PAUL-2A that reflect dry conditions in the Buck Creek floodplain ~10,200 and 9500 cal BP. Analysis of botanical remains from Connley Cave 5 found abundant wetland taxa in hearth features dated between ~12,000 and 11,500 cal BP but did not yield any evidence of wetland foraging in a hearth dated to ~10,200 cal BP (Chapter III). It is possible that declining use of Connley Caves and evidence of wetland exploitation there relates to reduced productivity of Paulina Marsh.

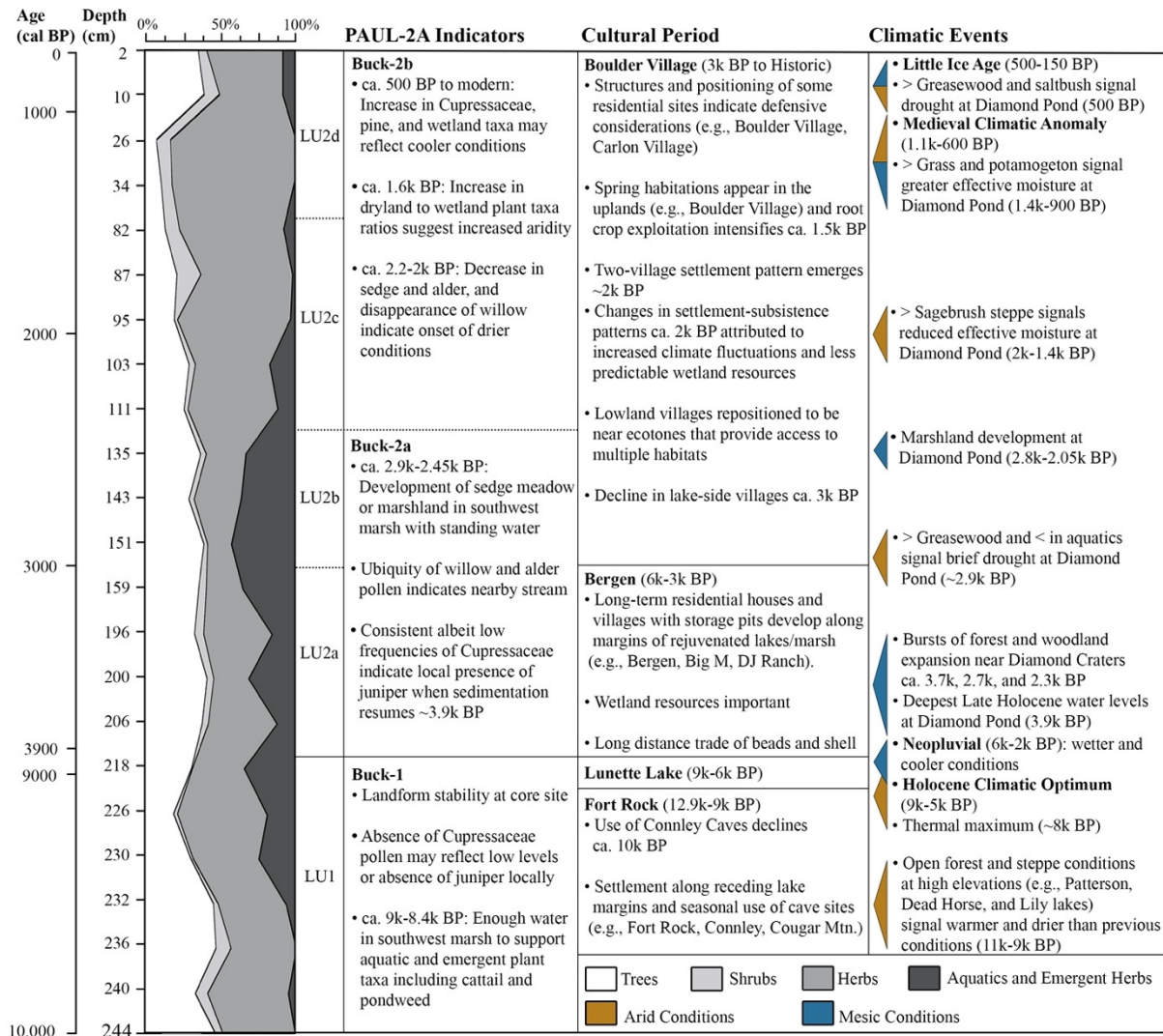


Figure 4.13. Comparison of vegetation proxy data from Paulina Marsh to northern Great Basin cultural periods, regional paleoenvironmental records, and global climatic events. All dates are shown in thousand calendar years before present (k BP).

The Lunette Lake Period (ca. 9000 to 6000 cal BP) is marked by low numbers of archaeological sites of predominantly short-term camps in dune settings (e.g., Locality III [Jenkins 2000]; Bowling Dune [Jenkins 2004], and Locality I [Mehring and Cannon 1994]). Researchers interpret this pattern as representing small, highly mobile groups who were spending short periods of time at camps located near lowland resource patches that had become less productive and more widely spaced due to deteriorating climatic conditions. Cascade point

assemblages at Connley Caves indicate recurrent periods of brief site use between ~9000 to 8000 cal BP (Bedwell 1970, 1973; Jenkins et al. 2017; McDonough et al. 2018; Saper et al. 2019). Increasing Cyperaceae and the presence of *Typha latifolia* in the PAUL-2A record suggest that a wetland or wet meadow developed in the Buck Creek floodplain during the first millennium of the Lunette Lake Period.

The Bergen Period (a. 6000 to 3000 cal BP) is characterized by population growth, increased sedentism, and resource intensification. Long term residential sites with substantial houses were established along the margins of rejuvenated lakes and marshes (Jenkins et al. 2004). Storage pits appear and wetland resources, especially fish, are considered of utmost importance based on faunal assemblages from sites in the Fort Rock Valley such as Bergen, Big M, GP2, and DJ Ranch (Greenspan 1994; Helzer 2001, 2004; Jenkins 1994; Jenkins et al. 2004; Moessner 2004; O’Grady 2004). Toward the end of this period, however, ca. 3500 cal BP, intensive occupations near marshes decreased. This decline in marsh use corresponds with rising frequency of Cyperaceae in the PAUL-2A record, however, the wet meadow conditions may have been less productive than the preceding millennia, which are absent from the pollen record. Coprolites from the Connley Caves dating between ~4200 and 3200 cal BP contained a variety of dryland and wetland seeds (e.g., *Typha*, rush [*Juncus*], and bulrush [*Scirpus*]), indicating that people foraged in the marsh (McDonough 2019; Chapter III).

The Boulder Village Period (ca. 3000 to historic contact) is characterized by significant changes in settlement-subsistence. Though marsh resources continue to be important, residential sites shift closer toward the uplands, and campsites in the uplands suggest intensified root exploitation. Between ~2000 and 1500 cal BP, groups in the Fort Rock Basin developed a “two-village settlement system” with the establishment of spring residential villages in the uplands

near root grounds (e.g., Boulder Village [Brashear 1994; Byram 1994; Jenkins and Brashear 1994]) and winter villages positioned in ecotonal settings (e.g., Carlon Village [Wingard 2001]). Researchers hypothesize that these settlement-subsistence shifts may have functioned as risk mitigation as resources became less predictable due to the increased tempo of oscillating climatic conditions and more dry intervals (Jenkins 1994). Though coarse grained, the PAUL-2A record indicates declines in wetland taxa within the last ~2000 years, generally supporting the idea that less productive or increasingly unpredictable marsh conditions may have contributed to peoples' transition toward alternative subsistence strategies.

1.24.6. Expression of Global Climatic Events

Proxy records from PAUL-2A contribute to the understanding of how global climatic events were expressed regionally. The onset of the Holocene is marked by a global rise in temperature ca. 11,700 cal BP that is apparent in Greenland ice cores and proxy data worldwide (Buizert et al. 2014; Grachev and Severinghaus 2005; Walker et al. 2019). PAUL-2A indicates that pluvial Lake Fort Rock had fully receded by at least 10,200 cal BP and that arid conditions persisted in the Fort Rock Basin until ~9500 cal BP, followed by climatic amelioration ~9500 cal BP. The Holocene Climatic Optimum coincides with an unconformity in PAUL-2A. While the unconformity prevents a reconstruction of vegetation during the Middle Holocene, it provides some clues regarding hydrologic history, as water levels in Paulina Marsh must have been very low prior to 3900 cal BP for the stream to have had such erosional power. In the Fort Rock Basin and neighboring areas, significant sand dune formation occurred following the desiccation of valley floors during the Holocene Climatic Optimum (Dugas 1998; Mehringer and Cannon 1994; Mehringer and Wigand 1986). If mesic conditions prevailed between ~6000 and 4000 cal BP, as indicated by pollen records in other basins, increased water flow could have contributed to the

erosional event. As such, the PAUL-2A record would fit with warming and drying trends of the Holocene Climatic Optimum.

During the Late Holocene, pollen in PAUL-2A shows high dryland to wetland ratios coincident with the Medieval Climatic Anomaly (ca. 1100 to 600 cal BP). This conflicts with some other pollen cores in the region that suggest mesic conditions at that time (Minckley et al. 2007; Wigand and Rhode 2002). The reappearance of Cupressaceae pollen in the PAUL-2A record within the last ~500 years generally coincides with a regional re-expansion of *Juniperus* woodland initiated by cooler temperatures and increased winter precipitation known as the Little Ice Age between 300 and 400 years ago (Mehring and Wigand 1990; Wigand and Rhode 2002). A decline in dryland to wetland ratios could also signal cooler conditions during the Little Ice Age, but higher resolution data are needed from Paulina Marsh to confirm the timing.

1.25. Conclusions

I draw the following conclusions with regard to the six original research questions. The PAUL-2A core site does not contain continuous terminal Pleistocene/Holocene sedimentary deposits due to an erosional unconformity caused by a meandering stream. The geomorphology of PAUL-2A, however, does confirm the presence of a buried soil dating to the Early Holocene and a continuous 3000-year Late Holocene sequence in the Buck Creek floodplain. While PAUL-2A does not contain a complete trans-Holocene sequence, it represents the first Early Holocene pollen record in the Fort Rock Basin and regionally is one of few lowland vegetation histories of this age in the northern Great Basin. As such, this study begins to fill an important gap for understanding past ecology and provides new context for interpreting the rich archaeological record of the Fort Rock Basin. The date of ~7550 cal BP (6690 ± 30 ^{14}C BP) at the base of PAUL-6 suggests that Middle Holocene-aged deposits are present elsewhere in the

marsh. It is possible that the longer cores obtained in 2019 contain Pleistocene deposits, although attempts to date PAUL-7H2 and the lower ~2 m of PAUL-2B have failed thus far due to low carbon content.

Palynological analysis of PAUL-2A verifies that pollen is preserved within Paulina Marsh, but reveals that preservation is not uniform and ranges from good to very poor. Variability in geomorphology, age, and preservation between the various cores confirms Benjamin's (1994) conclusions that Paulina Marsh is a complex hydrologic system and will require records from multiple locations to fully understand. Preservation of organic material appears to be better preserved in the southwestern marsh which has remained well watered; however, the hydrology of the floodplain makes it difficult to obtain a complete record and complicates palynological interpretations. Hydrology is less variable, and deposits are very deep in the northern marsh, but preservation of organic material appears to be poor (as demonstrated in the five failed radiocarbon dates), likely owing to many prolonged episodes of drying, and it is not clear if Holocene deposits are preserved there or have been eroded. Future work may be able to strike a compromise by using a Geoprobe to obtain a longer core from the relatively well watered central marsh where PAUL-6 contained enough organic material for radiocarbon dating.

The pollen record from the Paulina Marsh corresponds well with regional environmental records, including the representation of certain global climatic events, and supports proposed human palaeoecological models for the Fort Rock Basin. Dry conditions in the marsh during the Early Holocene coincided with the global warming trends and with decreased human activity at the adjacent Connley Caves archaeological site. The unconformity in PAUL-2A may be due to arid conditions during the Holocene Climatic Optimum followed by marsh resurgence. A wetland or wet meadow was present in the Buck Creek floodplain during the Late Holocene until

~2000 cal BP when wetland taxa decline. This shift corresponds with a major settlement-subsistence change among foragers in the Fort Rock Basin and supports the hypothesis that intensification of upland resource exploitation may relate to unpredictable marsh resources. The Medieval Climatic Anomaly warm period generally corresponds with high dryland to wetland ratios in the PAUL-2A record, suggesting this event affected local vegetation. The impact of the Little Ice Age is less clear due to low sampling resolution. In sum, the emerging view of hydroclimate and vegetation history in the Fort Rock Basin generally corresponds with climatic and cultural models for the region, but more cores and pollen analyses are needed to refine this initial record. The results from this study indicate that future work has great potential to provide data critical to archaeological, biogeographical, and paleoenvironmental research in the northern Great Basin.

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CHAPTER V

CONCLUSIONS

The multiproxy data presented in this dissertation provide new perspectives on human-plant relationships in the Great Basin since the terminal Pleistocene. The previous chapters are united by the overarching theme of human paleoecology, with primary topics including the role of plants in forager food economies and the dynamics between climate, vegetation, and cultural practices. I investigated these questions through the integration of archaeobotanical, palynological, archaeoparasitology, and geomorphological data derived from materials excavated from Connley Cave 5 and sediment cores extracted from Paulina Marsh in the Fort Rock Basin of central Oregon. In addition to implications for human paleoecology in the northern Great Basin, the results and methods of this dissertation research are widely applicable to studies of Paleoindian lifeways, settlement-subsistence organization, and influences of climate change on human and plant communities. I summarize the major findings and implications of this research in relation to each of these topics below.

1.27. Paleoethnobotanical Perspectives on Paleoindian Lifeways

Paleoethnobotanical approaches are critical for understanding past lifeways yet continue to be underrepresented in Paleoindian research. I address this issue in Chapter II through the presentation of new botanical and radiocarbon data from five combustion features within stratified cultural components at Connley Cave 5 that reaffirm the importance of plants in the diet of Paleoindian groups. Botanical remains from three features (ca. 12,000 to 11,500 cal BP) show that people foraged for a diverse range of dryland taxa and narrower range of wetland taxa during summer and fall months. I developed a set of criteria based on the abundance, spatial

distribution, ecology, and ethnographic use of each plant taxa to evaluate the probability of dietary association. Foraged plants included several taxa that are new to the known Pleistocene plant food economy of North America (buckwheat, peppergrass, and seepweed), as well as a variety of plants reported from other Paleoindian sites in the Great Basin (dropseed sandgrass, goosefoot, pigweed, ricegrass, rush, saltbush, and the sunflower family). Features also yielded charcoal, charred starchy and fruity plant tissue, sap, bone, eggshell, feathers, debitage, and two bone needles. Variability in feature constituents reflects differences in the seasonality and purpose of site use through time, and the appearance of plant foods from multiple habitats in the same feature may reflect divisions in labor. Together these data form one of the most robust views of Paleoindian plant use in the Americas.

In addition to providing new insights on human behavior at a site level, archaeobotanical data from Connley Caves contribute to an emerging pattern in the Pleistocene archaeological record indicating that regionally adapted subsistence strategies were in place among Paleoindian groups by at least the Younger Dryas. My review of archaeological dietary records from late Pleistocene contexts in temperate North America found that plant remains are generally rare in sites predating 11,700 cal BP, but are present in every region of by ~10,000 cal BP. Of the existing Pleistocene-aged archaeobotanical assemblages, those in the Great Basin have yielded a greater diversity of taxa, including small seeds, fruits, roots, and edible plant tissue, relative to sites farther east that are dominated by fruits and nuts. These data support the hypothesis that groups equipped with Western Stemmed Tradition toolkits had broad, flexible diets, and may have incorporated a wider range of plants into their food economies earlier than contemporaneous groups using other technocomplexes.

The recurring appearance of plants that rank low in terms of energetic return rates suggests that variables other than caloric maximization drove some plant foraging choices, and I propose that principles from nutritional ecology may explain such behavior. Nutritional ecology examines the relationship between human health and nutrient intake, recognizing that optimal health requires a suite of macronutrients (e.g., carbohydrates, fats, and proteins) and micronutrients (e.g., vitamins and minerals). Therefore, diverse, nutrient-rich diets provide better nutritional frameworks for successful growth and reproduction. My comparison of available nutritional data for taxa recovered from Paleoindian sites shows that plant foods are the best sources for myriad essential nutrients and demonstrates the potential for nutrient acquisition to explain certain aspects of food selection. Nutritional ecology presents an explicit theoretical framework for understanding the principles behind subsistence choices, health, and fertility. As such, this approach is relevant to major questions and debates in Paleoindian research concerning population growth, cultural variation, social organization, and subsistence strategies during the first few millennia of humans arriving in North America.

1.28. Settlement-Subsistence and Dietary Datasets during the Holocene

In Chapter III, I investigate aspects of diet, seasonal subsistence strategies, and human health through the integration of palynological, macrobotanical, faunal, and parasitological data from 16 coprolites dating to the Bergen Period (ca. 5700 to 3200 cal BP) at Connley Cave 5. Multiproxy dietary constituents in the coprolites show that foragers consumed seeds, fruits, plant tissue, mammals, birds, and fish from dryland, wetland, and, to a lesser extent, upland habitats. Groups repeatedly visited the site during the late summer/early fall, but at least a segment of the group did not consume wetland resources during certain visits. Several of the most abundant plant taxa were previously unrecognized within the Bergen Period food economy (cattail, rush,

and sumac), whereas many others, particularly seeds of the grass and amaranth families, are common at prominent coeval archaeological sites in the Fort Rock Basin lowlands. This study complements and expands the known dietary breadth of the Bergen Period and provides the first detailed look at the Middle Holocene archaeological record at Connley Caves.

As the first coprolite analysis for this time period in the northern Great Basin, this chapter contributes a unique dataset that complements and informs regional human paleoecological models. Middle Holocene archaeological records in the northern Great Basin indicate a shift from a highly mobile foraging strategy during the Lunette Lake Period (ca. 9000 to 6000 cal BP) to a more sedentary, collector-like strategy during the Bergen Period (ca. 6000 to 3000 cal BP). A significant decline in the archaeological record of rockshelter sites in the Great Basin reflects a change in the use of these locations during the Middle Holocene, and substantial residential sites in the Fort Rock Basin suggest that groups spent much of the year in hamlets positioned near marshes. Continuity between the plant taxa represented in the coprolites from Connley Caves and charred botanical remains from hearths and caches recovered from lowland residential sites suggest that Connley Cave 5 may have served as an important fall foraging area and temporary habitation for task groups. This scenario fits well with the prevailing settlement-subsistence model for the Bergen period, which proposes that upland and hillside resources were obtained through logistical forays, with collected resources brought back to lowland base camps. The coprolites from Connley Caves provide a novel view of rockshelter use during the Bergen Period and reveal aspects of human health and diet that are usually difficult to see archaeologically.

This study also offers broader implications for interpreting subsistence remains from archaeological contexts. First, the human origin of coprolites should not be disqualified based on the inclusion of items that appear odd or non-palatable from the analyst's cultural perspective.

For example, some researchers may have attributed coprolite C12 to a non-human mammal based on the wad of netting it contained; however, subsequent analysis of the fecal biomarkers confirmed human origin. This raises questions about the interpretation of coprolites containing cordage at other archaeological sites. Second, coprolites provide invaluable information for subsistence research because they often reveal dietary items that do not preserve or are difficult to interpret in most archaeological contexts. For example, cattail seeds are hard to recover and have been attributed to non-dietary functions due to their minuscule size; however, the density of such seeds in coprolites from Connley Cave 5 shows they were intentionally consumed and should not be discounted as dietary components. Third, the taphonomy of the coprolite constituents contributes to our understanding of biases in the archaeological record. The lack of carbonization among many of the seeds indicates they were consumed raw or possibly boiled. Such preparation practices give little opportunity for plants to become charred and preserved, thus they are very likely underrepresented in recognized food economies. Finally, this study exemplifies the power of coprolites to reveal aspects of diet and decision making at an individual scale—a perspective that is seldom achieved archaeologically. In conclusion, coprolites from Connley Caves contribute high-resolution, multiscalar data from a unique site-type (rockshelter) that strengthens the existing settlement-subsistence record in the northern Great Basin and provides pertinent information to the broader field of coprolite research.

1.29. Paulina Marsh’s Emerging Paleoclimatic Record

In Chapter IV, I present the results of my coring project in Paulina Marsh aimed at filling the gap in local paleovegetation records from lowland settings in the northern Great Basin. My analysis of PAUL-2A, a 2.47-m-long sediment core from the Buck Creek floodplain in the southwestern marsh, revealed shifts in hydrology and plant communities during the Early and

Late Holocene. Palynology and geomorphology of the core indicate arid conditions between ~10,200 and 9500 cal BP, followed by the establishment of emergent wetland plant taxa by 9000 cal BP. The Middle Holocene is absent from the record, likely due to an erosional unconformity between the Early and Late Holocene components. During the Late Holocene, wetland conditions persisted between ~3900 and 2200 cal BP, followed by a decrease in wetland taxa and establishment of the current dryland-taxa dominated plant community. This study represents the first attempt at analyzing sediment cores from Paulina Marsh and resulted in the first Early Holocene pollen record for the Fort Rock Basin. Past studies of pollen cores dating to the Early Holocene in the northwestern Great Basin focused primarily on high-elevation lakes (e.g., Deadhorse Lake [Minckley et al. 2007]; Wildhorse Lake [Mehring 1985]; and Fish Lake [Mehring 1985]), so this study provides an important complementary perspective from a lowland setting. Paul-2A and the new provenience and chronological data that I present on four additional sediment cores also establish a solid framework for future work in Paulina Marsh.

Available paleoenvironmental records show that global climatic shifts did not occur uniformly across the Great Basin; therefore, developing local vegetation and hydrologic records for the Fort Rock Basin is critical for understanding climate change in the northwestern-most region and for contextualizing the area's rich archaeological record. The basal component of PAUL-2A shows that pluvial Lake Fort Rock had fully receded by ~10,200 cal BP, coincident with global warming trends during the Early Holocene. Impacts of the Holocene Climatic Optimum and Neopluvial periods are difficult to interpret because both events mostly fall within the unconformity. It is possible that decreased alluviation or deflation during the former and increased water flow during that latter contributed to the unconformity, but more cores must be analyzed to test those possibilities. The Medieval Climatic Anomaly corresponds with high

dryland to wetland pollen ratios indicating xeric local conditions, a pattern that conflicts with other regional records that suggest mesic conditions during that time. The slight uptick in Cupressaceae pollen during the last ~500 years could reflect cooler conditions, but higher resolution data are needed to pinpoint this possible correlation. Overall, climatic indicators in PAUL-2A align well with proposed human paleoecological models for the northern Great Basin. Rising wetland taxa during the Fort Rock and Bergen periods correlate with predictions for increased focus on recently established or rejuvenated marshes. Declining wetland taxa around 2000 cal BP support the idea that less productive or increasingly unpredictable marsh conditions contributed to major settlement-subsistence shifts during the Boulder Village Period.

Insights from this study are also relevant to ongoing land management efforts in response to impacts of western juniper expansion. The occurrence of western juniper has increased approximately ten-fold since 1870, and its spread has major impacts for sagebrush steppe ecosystems and watersheds. The paleobiogeography of western juniper is important for restoration and conservation efforts seeking to manage these effects (Miller et al. 2005; Miller et al. 2019). Western juniper is a hallmark in the Fort Rock Basin today, but when it became established there is unknown and may have been later than in neighboring basins. The dearth of Cupressaceae pollen in the Early Holocene component of PAUL-2A suggests that the trees were locally sparse or absent prior to ~8200 cal BP. Western juniper is used for fuel, tool making, food, and medicine by Indigenous groups, and would have been an important resource for past populations. As such, understanding the initial spread of western juniper in the region, and reconstructing vegetation histories more broadly, is relevant to archaeologists, land managers, conservationists, and members of the public.

In sum, this study has shown that despite its complex depositional history, Paulina Marsh contains preserved pollen sequences and other important climatic proxy records that are worth pursuing. Though more work in Paulina Marsh is needed, my dissertation research is a step toward the development of a locally refined vegetation history that is critical for interpreting the rich archaeological record and biogeography of the Fort Rock Basin.

1.30. Future Studies

High-resolution dietary and environmental data are key to recognizing the interconnections of climate change, seasonal mobility, foraging choices, and population dynamics. My dissertation contributes to that effort and will conclude by outlining potential pathways for future research, particularly with regard to human nutrition, foraging behavior, and paleoenvironments.

1.30.1. Human Nutrition and Foraging Choices

Analysis of the faunal and artifact assemblages from the terminal Pleistocene and Early Holocene cultural components at Connley Caves would provide a more holistic view of human behavior. Zooarchaeological analysis is sorely needed to complement the existing paleoethnobotanical data. Specifically, the possibility for fishing should be investigated through faunal analysis of features 2 and 4. Analyses of the extensive and diverse tool assemblages associated with the Paleoindian cultural components are also needed to fully interpret the nature of site use. Comparison of toolkits from cultural components containing evidence of plant use to those lacking such evidence may help identify tools associated with plant procurement or processing. The integration of botanical, faunal, and artifact datasets would generate an exceptionally robust framework for understanding patterns of site use and Paleoindian foraging behavior more broadly. Multiproxy analyses of older and younger cultural components from

Cave 5 and other rockshelters within the Connley Caves complex would improve our understanding of diachronic and spatial patterns of site use. Ultimately, a transcontinental review of all subsistence data from Paleoindian sites is needed to assess and quantify issues related to sampling, taphonomy and other variables that are undoubtedly biasing the archaeological record.

My analysis of coprolites from Connley Cave 5 could be expanded through examination of more specimens and with the application of other dietary proxies, such as phytoliths, starches, hair, and DNA. A full analysis of the associated artifact assemblages is necessary for fully contextualizing these data and for understanding the Holocene occupations at Connley Caves. Finally, DNA analysis of tapeworm eggs in coprolite sample C12 is needed to determine the species of Taeniid in the specimen. This is important for investigating human health at multiple archaeological sites in the Great Basin and Southwest where tapeworm eggs have been found in coprolites and is also relevant to unraveling the life history of Taeniidae and human-parasite relationships in North America.

In my view, one of the most exciting avenues for future research is through nutritional ecology. Specifically, the nutritional geometry framework provides a method of multidimensional modeling that incorporates the interactions of dietary components and their effects on physiology, development, behavior, and other systems. Raubenheimer and Simpson (2018) recently proposed the use of nutritional geometry to integrate key aspects of optimal foraging theory and nutritional ecology with applications to many fields in biology and biomedicine. The multivariate and nutritionally explicit perspectives of this approach may also provide a new way forward in anthropological science, particularly for understanding the relationships between environment, foraging choices, fertility, and population growth in prehistory. Balanced nutrition is critical to fertility and reproduction and should therefore be of

primary concern to Paleoindian research where population dynamics, settling-in processes, and subsistence strategies are principal topics.

1.30.2. Paleoenvironmental Research

Sediment core data presented in Chapter III confirmed that geomorphology and pollen preservation in Paulina Marsh is highly variable, and the only way to fully understand the marshes' history is to study cores from multiple locations. This is something I intend to pursue through future analyses of additional cores and integration of other proxy data such as diatoms, charcoal, and isotopes. Palynological analysis of a sediment column and charcoal from Connley Caves would provide complementary paleoclimatic records and may also help elucidate the timing of juniper expansion into the Fort Rock Basin. Future coring endeavors may find success in the central and southeastern marsh where hydrological systems are less complex, but pollen preservation is still probable. There is a continued need for high-resolution paleoenvironmental records from lowland contexts in the northern Great Basin. Any and all studies of paleoenvironment and vegetation histories provide important context for archaeological research. We will never have enough of these records, and we should continue striving to obtain and refine them.

1.31. Conclusion

My dissertation highlights the importance of paleoethnobotanical approaches and integration of multiproxy datasets to answer central questions within human paleoecology, particularly those of foraging behavior, seasonal mobility, and human adaptation to climate change. Datasets presented in this dissertation are multiscale in that their components are both microscopic and macroscopic, but also in that they impact our view of human-plant relationships on individual, regional, and continental scales. Subsistence data from Connley Caves

demonstrate that people incorporated a wide range of plants in their diets, even during the terminal Pleistocene, and sediment cores from Paulina Marsh provide crucial contextual data for archaeological interpretation, paleoenvironmental modeling, and conservation efforts. Plants are vital to human life, be it for food, fuel, shelter, tools, among other functions; accordingly, paleoethnobotany is essential for understanding human behavior. Careful recovery and detailed interpretation of botanical remains is especially imperative for advancing Paleoindian research, where our view is largely confined to the lenses of faunal and lithic analyses. As we continue to develop more and more fine-grained datasets reflecting how plants were selected, when they were gathered, and why their biogeography changed over time, the more capable we will be of resolving broad-scale questions about human-environmental relationships and leveraging that knowledge for the future.

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APPENDIX A

SUPPLEMENTARY DATA FOR CAVE 5 COMBUSTION FEATURES, STRATIGRAPHY, AND RADIOCARBON SAMPLES

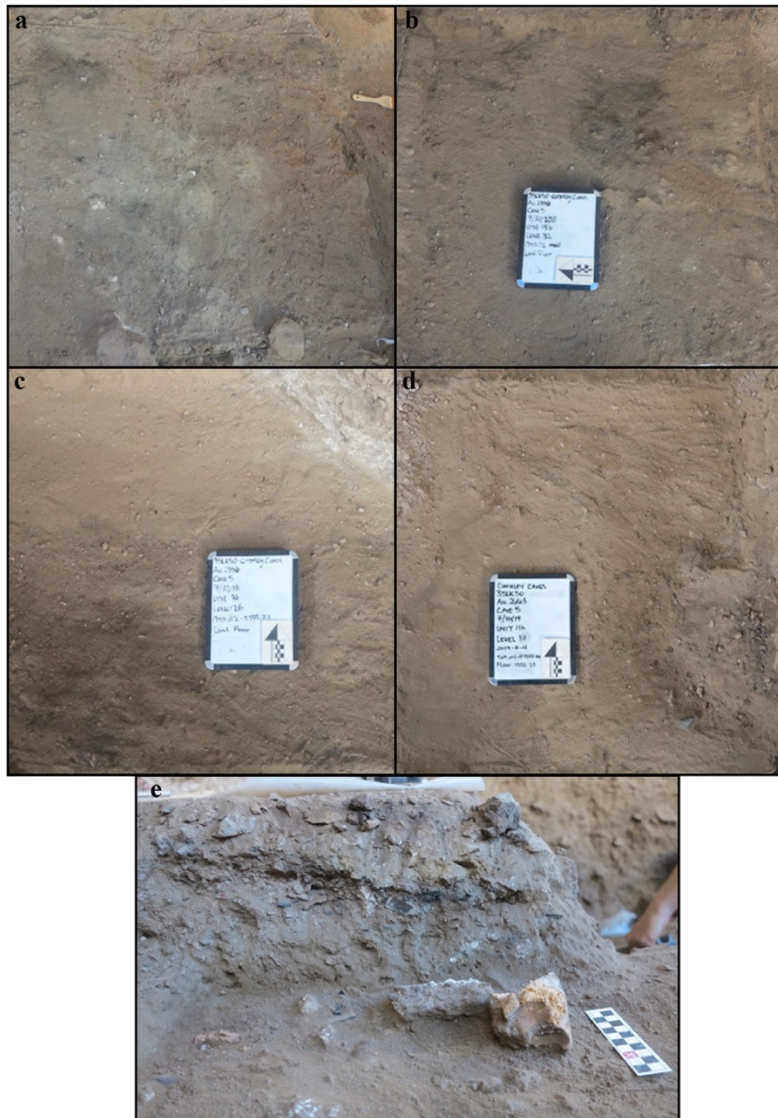


Figure A.1. Images of Features 1 and 2: (a) Feature 2 exposed at 1355.81 m ASL in Unit 15B; (b) Feature 2 exposed at 1355.76 m ASL in Unit 15B; (c) northern part of Feature 2 exposed at 1355.72 m ASL in Unit 26; (d) plan view of Feature 1 at 1355.66 m ASL with floor 1355.65 m ASL in Unit 15B; (e) Unit 15B east wall profile view of Feature 1 with *Cervus* tibia in situ at 1355.53 m ASL, below Feature 1.



Figure A.2. Images of Feature 3, 4, and 5: (a) plan view of top of Feature 4 at 1355.99 m ASL in Unit 25, notice rubified and ashy sediments; (b) plan view of Feature 4 after excavation and collection with projectile point (Figure A.3e) in situ denoted by arrow; c: west facing profile view of Feature 4; (d) plan view of Feature 3 at 1355.75 m ASL in Unit 17; (e) plan view of Feature 5 at 1355.87 m ASL in Unit 18; (f) plan view of Feature 3 during excavation with large mammal bone (northeast of photo board) and projectile point (Figure A.3d) in situ denoted by arrow.



Figure A.3. Representative lithic and osseous artifacts from recent University of Oregon Connley Cave 5 excavations. Eye details of needles (m-n) are same scale as p-r. Arrow points to graver bit and dotted lines denote working edge of scrapers. Catalog numbers are listed in parentheses after artifact descriptions: (a) refit Haskett point (2556-2361 and 2256-2279); (b) recycled Haskett point (2263-499); (c) probable Haskett base (2556-3312); (d) probable Haskett base (2556-3522); (e) possible Cougar Mountain point (2556-1259); (f) WST/Cascade base (2458-1722); (g) hafted end scraper (2556-3440); (h) end scraper (2663-1728); (i) hafted end scraper (2556-1333); (j) modified flake/perforator (2663-235); (k) graver (2663-238); (l) composite fishhook (2556-1538); (m) bone eyed-needle (2556-380 and 2556-381); (n) bone eyed-needle (2556-2530); (o) bone eyed-needle (2556-3567); (p) bone eyed-needle (2556-1150); (q) bone bead preform #1 (2556-2572); (r) bone bead preform #2 (2556-3572). Feature 1: a, b, h; Feature 2: n; Feature 2/3: c, d, g, i, j, k, n, o, q, r; Feature 4: e, l, m, p; Feature 5: f.

Table A.1. Feature proveniences and descriptions.

Feature Number	Original Number	Type	Elevation (m ASL)	Length (cm)	Width (cm)	Max depth	Description	Evidence for disturbance?	Sampling	Comments
1	15B-HF-2	Hearth	1355.66-1355.56	60	25	10	First appeared as a laterally discontinuous brown (7.5YR-4/4), light brownish gray (10YR-6/2), and light yellowish brown (10YR-6/4) ashy silt with clear boundaries. Hearth retains original bedding and firing structure as indicated by stratified charcoal, probably wood ash, and rubification with large, carbonized wood fragments. Gypsification present. The primary burning portion of the feature ranges from 1355.66-1355.56, but a larger area, extending to 1355.46 was affected by the intense heat of the fire producing ashy and rubified sediments further down..	The feature was well preserved with no evidence of krotovina or other disturbances.	We collected all of the feature fill, bulk samples from outside of the feature for comparison, and Justin Holcomb took a block sample from the western wall of unit 17 for micromorphological analysis.	Unit 15b bisected the feature, exposing its bowl-shaped profile in the east wall. The eastern half of the feature was not excavated and is still preserved in Unit 17.
2	15B-HF-1	Combustion Area	1355.87-1355.71	~125 max	~90 max	~16	The combustion area first appeared in Unit 15B at 1355.87 m ASL as a distinct concentration of charcoal fragments within patches of dark grey (10YR-4/1) ash and light brownish grey (10YR-6/2) ashy silt in the northwest quadrant of unit 15B. Charcoal staining expanded with depth and mottling continued until ~1355.71 m ASL, when ash became concentrated in the northeast quadrant and was underlain by patches of dark yellowish brown (10YR-4/4) silty loam. Much of the feature consisted of irregular patches of ash and dispersed charcoal with diffuse boundaries.	No evidence of rodent disturbances or Mazama tephra; however, the feature is patchy, irregular, and discontinuous in places.	Bulk samples taken throughout.	
3	17-HF-1	Hearth Area	1355.85-1355.70	60	22	~15	Burned area first encountered in level 50. Hearth fill is characterized by large amounts of charcoal fragments, staining, microdebitage and bone. Large bone fragments found under cobbles. Area within cobble ring contained charcoal staining that continued out toward the area northwest of the cobble ring. Unclear if this is one or two features. Feature fill was distinct from surrounding sediment. Sediment outside of the feature area was yellowish brown (10YR 5/4) silty loam with increasing rock content (30% in level 51 up to 40% in level 52). The boundary between hearth feature and surrounding sediment was consistently abrupt and distinct. Charcoal concentrations shifted with depth; first appearing in level 50 along the west wall, expanding into central area beneath large cobbles and splitting into two concentrations—one in the west and one in the east—in level 52.	Preservation was very good and we observed no krotovinas or other disturbances.	Total collection of fill within rock ring. Charcoal area extending to northwest sampled. Bulk samples also taken from the eastern quadrants of Unit 15B. Surrounding sediment was excavated separately, and samples were taken for comparison.	Unclear whether this is one large feature or two separate features/burning events.

Feature Number	Original Number	Type	Elevation (m ASL)	Length (cm)	Width (cm)	Max depth	Description	Evidence for disturbance?	Sampling	Comments
4	25-HF-2	Hearth	1355.99-1355.93	57	50	10	The hearth boundary was abrupt, and the fill consisted of moderately sorted very dark brown (10YR-2/2) silt with charcoal, burned bone, and debitage. We encountered white flecks that may be phosphate throughout, and the base of the feature was rubified.	Preservation was good and we observed no krotovinas or other disturbances.	Excavators removed the eastern half of the feature first to expose a profile through the center of the hearth. We then drew a profile and took micromorphological and bulk samples from within the feature.	Preservation was good and we observed no krotovinas or other disturbances.

Table A.2. Description of lithostratigraphic units (LU) in Connley Cave 5.

LU	Description	Interpretation
1	Rounded and subrounded cobbles and gravels of mixed lithology in loose dark yellowish brown (10YR 4/4) silt loam. Clast supported. Lower boundary unobserved.	Lacustrine sediments
2	Moderately cemented yellowish brown (10YR 5/4) and brown (10YR 4/4) mottled silt with platy to subangular blocky structure. Moderate to hard consistency overlapping LU1 and LU2 contact. Lower boundary is conformable and abrupt and wavy.	Eolian sediments
3	Well-sorted yellowish brown (10YR 5/4) silt with common fine angular gravels. Massive. Lower boundary appears conformable and is clear and wavy.	Eolian sediments
4a	Moderately sorted brown (10YR 4/3) silt with many fine angular gravels. Loose consistency. Gypsiferous. Clear smooth lower boundary dips to the north and appears erosional.	Eolian and colluvial sediments
4b	Moderately sorted brown (10YR 4/3) silt with many fine angular gravels. Gypsiferous (increase from underlying unit). Loose consistency. A lower boundary dips to the south and is clear and wavy.	Eolian and colluvial sediments
5	Moderately to poorly sorted brown (10YR 4/3) silt with few angular cobbles and many angular gravels. Loose consistency. Occasional laterally discontinuous patches of many fine gravels. Lower boundary is erosional marked by an abrupt and wavy unconformity.	Eolian and colluvial sediments

Table A.3. Provenience and radiocarbon results of feature charcoal samples.

Unit	Level	N	E	m ASL	LU	Ft #	Catalog Number	Lab Number	¹⁴ C Date
18	53	58	65	1355.87	5	5	5/18-53-7 ^a	PSUAMS#5246	9050±30
18	53	61	74	1355.89	5	5	5/18-53-10	D-AMS 24523	9170±40
S18	53	46	80	1355.88	5	5	5/18-53-12 ^a	PSUAMS#5247	9500±30
25	15	47	56	1355.99	4b	4	5/25-15-35 ^a	PSUAMS#5007	9985±35
25	15	56	26	1356.01	4b	4	5/25-15-41	PSUAMS#6711	10,165±35
25	16	43	59	1355.97	4b	4	5/25-16-4	D-AMS 30300	10,010±50
25	16	29	48	1355.98	4b	4	5/25-16-64 ^a	PSUAMS#5006	10,210±40
17	51	36	57	1355.75	4b	3	5/17-51-95	D-AMS 30299	10,115±50
17	51	34	59	1355.75	4b	3	5/17-51-96 ^a	PSUAMS#5008	10,120±35
17	50	38	37	1355.82	4b	3	5/17-50-12 ^a	PSUAMS#5009	10,190±35
15B	31	81	24	1355.81	4b	2	5/15B-31-50	D-AMS 30298	10,030±95
15B	32	63	34	1355.77	4b	2	5/15B-32-25	PSUAMS#7103	10,150±40
15B	32	76	76	1355.76	4b	2	5/15B-32-38	PSUAMS#6712	10,275±35
15B	32	89	24	1355.79	4b	2	5/15B-32-21	PSUAMS#7104	10,290±35
15B	36	35	95	1355.57	4a	1	5/15B-36-50	PSUAMS#6715	10,420±35
15B	36	26	99	1355.60	4a	1	5/15B-36-49	PSUAMS#6714	10,490±35
15B	36	34	98	1355.58	4a	1	5/15B-36-51	PSUAMS#6716	10,560±35

Notes: LU is Lithostratigraphic Unit; N is northing; E is easting; Ft# is feature number.

^aPretreated at UNR Human Paleoecology and Archaeometry Lab.

Table A.4. Quantity, density, and diversity of taxa found in Connley Caves feature samples. All feature samples were 1 liter in volume.

Feature Number		1 (15b-HF-2)		2 (15b-HF-1)		3 (17-HF-1)			4 (25-HF-2)		5 (18-HF-1)		Ubiquity in Features (%)	Ubiquity in Column (%)
Catalog number		1184	1618	2530	3027	1781	2460	1994	1079	1150	1968	1969		
Elevation (cm below 1356.5 masl)		84-93	95	63	69-74	65	68	75	51	53-58	61-63	61-63		
Seed total		1	2	45	534	11	40	43	279	166	1	4		
Shannon index		0	0.012	1.185	1.377	0.86	1.751	1.48	1.396	1.053	0	0.562		
Species richness		1	2	5	14	3	10	9	13	9	1	2		
Evenness		0	0.334	0.736	0.522	0.783	0.761	0.68	0.678	0.503	-	0.811		
<i>Wetland Seeds</i>	Bulrush-type	-	-	-	-	-	-	-	-	-	-	-	-	6
	Cattail	-	-	-	7	-	-	-	9	1	-	-	27	6
	Cattail, UNCH	-	-	10	297	-	-	-	23	-	-	-	27	-
	Mare's tail	-	-	-	1	-	-	-	-	-	-	-	9	-
	Rush-type	-	-	-	-	-	-	-	2	-	-	-	9	-
	Sedge	-	-	-	-	-	-	-	-	-	1	-	9	-
	Spikerush	-	-	-	1	-	-	-	-	-	-	-	9	-
<i>Dryland Seeds</i>	Amaranth family	-	2	26	94	7	13	20	101	102	-	3	82	41
	Buckwheat	-	-	-	18	-	-	1	25	-	-	-	27	-
	Dropseed	-	-	-	1	-	-	-	-	4	-	-	18	6
	Goosefoot	-	-	3	11	1	2	2	3	2	-	1	73	35
	Grass family	-	-	-	-	-	1	-	1	-	-	-	18	6
	cf. Mallow	-	-	-	1	-	-	-	-	-	-	-	9	-
	cf. Ricegrass	-	-	-	-	-	1	-	-	-	-	-	9	-
	Peppergrass	-	-	-	2	-	-	-	5	8	-	-	36	-
	Pigweed, UNCH	-	-	-	-	-	-	1	-	-	-	-	9	-
	Sagebrush	-	-	-	1	-	1	1	12	-	-	-	36	-
	Saltbush	-	-	2	17	-	5	3	4	1	-	-	55	6
	Seepweed	-	-	-	11	-	1	-	5	1	-	-	36	-
	Sunflower family	-	-	-	-	-	-	1	-	-	-	-	9	-
	Blazingstar	-	-	-	-	-	-	-	1	-	-	-	9	-
cf. Phacelia	-	-	-	-	-	1	-	-	-	-	-	9	-	
<i>Wetland or Dryland</i>	Dodder	-	-	-	-	-	1	-	1	-	-	-	18	6
	Dodder, UNCH	-	-	-	-	-	-	-	5	3	-	-	18	24
	Knotweed	-	-	-	-	-	2	-	-	-	-	-	9	-
	cf. Viola	-	-	-	2	-	-	-	-	-	-	-	9	-
	Unid.	1	-	4	70	2	9	13	68	43	-	-	73	35
	Unid., UNCH	-	-	-	-	1	4	-	14	1	-	-	36	6
<i>Other Vegetal Material</i>	Charcoal (g) ^b	8.44	3.41	14.03	11.96	8.2	6.05	4.51	3.05	3.66	4.65	2.59	100	65
	Sclerotia	-	-	-	-	3	2	3	-	1	-	-	27	-
	Sclerotia, UNCH	-	-	-	-	-	2	4	-	-	-	-	18	-
	Charred tissue	-	-	P	P	P	P	P	P	P	-	-	64	-
	Other	-	-	sap	-	nutlet	bud	bud	-	-	-	-	18	-
<i>Faunal</i>	Bone (g) ^b	2.03	2.76	14.46	6	35.75	9.48	9.19	28.72	21.11	1.55	2.69	100	94
	Fish vertebra	6	7	37	71	8	40	23	213	214	12	4	100	59
	eggshell (E); feathers (F)	-	-	-	E	E	E	E	E	E, F	-	-	55	-
<i>Misc.</i>	Debitage	28	39	188	87	416	633	439	66	55	11	17	100	71
	Bone needle	-	-	1	-	-	-	-	-	1	-	-	18	-

Notes: All seeds are charred unless indicated as uncharred (UNCH). Charcoal and bone are reported in weight (g).

Table A.5. Names of taxa found in Connley Caves features.

Family	Genus/ species	Common Name	Klamath	Modoc	Northern Paiute
Amaranthaceae	<i>Atriplex</i>	saltbush/ shadscale	-	-	<i>kangibbi; yinnaka</i>
Amaranthaceae	<i>Amaranthus</i>	pigweed	<i>bä-lō'- ōch</i>	<i>ba'kai?</i>	<i>iapi</i>
Amaranthaceae	<i>Chenopodium</i>	goosefoot	<i>kōts-on'- iks</i>	<i>kotca'niks</i>	<i>i'api</i>
Amaranthaceae	<i>Suaeda</i>	seepweed	-	-	<i>wada</i>
Asteraceae	<i>Artemisia</i>	sagebrush	<i>ghät, or bōl'- whē</i>	<i>cqo't; bu'lxwi</i>	<i>sawabi</i>
Brassicaceae	<i>Lepidium</i>	peppergrass	-	-	-
Plantaginaceae	<i>Hippuris</i>	mare's tail	-	-	-
Convolvaceae	<i>Cuscuta</i>	dodder	-	-	<i>atsannatsakwisadt tibbuzi (C. eseulentus)</i>
Cyperaceae	<i>Cyperus</i>	sedge	-	-	-
Cyperaceae	<i>Eleocharis acicularis</i>	spikerush	-	-	<i>pamahabi sai-</i>
Cyperaceae	Scirpus-type	bulrush, tule	<i>mä-i</i>	<i>ma'i; kla'na</i>	<i>sai-; abibibui</i>
Hydrophyllaceae	<i>Phacelia</i>	phacelia	-	-	-
Juncaceae	<i>Juncus</i> -type	rush	<i>tsin'ä'-ō</i>	-	<i>pamahabi</i>
Loasaceae	<i>Mentzelia albicaulis</i>	whitestem blazingstar	<i>lō'-läs</i>	<i>lo'las</i>	<i>kuha</i>
Malvaceae	<i>Sphaeralcea</i>	desert mallow	-	-	<i>piipinoodi</i>
Poaceae	<i>Achnatherum hymenoides</i>	Indian ricegrass	-	-	<i>wai; waipui</i>
Poaceae	<i>Sporobolus</i>	dropseed	-	-	-
Polygonaceae	<i>Eriogonum</i>	buckwheat	<i>ba-bäk"-- bak- lha'- näm</i>	<i>qa'lupka</i>	<i>tazawazubi</i>
Polygonaceae	<i>Polygonum</i>	knotweed	-	-	-
Typhaceae	<i>Typha</i>	cattail	<i>pō'-päs</i>	<i>pu'pasam</i>	<i>tahuunatsi; toi'i; toibi</i>
Violaceae	<i>Viola</i>	violet	-	-	-

Table 4.6. Quantity of taxa found in Connley Caves column samples.

Sample number	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	
Stratum	D	D	D	D/C	C	B	B	B	B	B	B	B	B	B	B	B	Krot.	
Elevation (cm below 1356.5 masl)	140-125	125-120	120-115	115-110	110-105	105-100	100-94	94-90	90-85	85-78	78-75	75-70	70-55	55-48	48-45	45-40	40-28	
Volume	0.5	0.5	0.4	0.35	0.5	0.5	0.25	0.4	0.4	0.6	0.275	0.325	0.625	0.45	0.15	0.55	0.5	
Weight	765.1	725.9	575.7	485.2	644.4	605.8	361.6	489.6	520.4	802.7	397.5	483.8	822.6	641.9	240	804.3	673.7	
Seed total (NISP)	0	0	0	0	0	0	0	3	3	2	0	4	5	8	1	9	10	
Charred seed density per 1 l	0	0	0	0	0	0	0	8	8	2	0	12	8	16	7	13	20	
Seeds	Amaranth family	-	-	-	-	-	-	2	1	-	-	2	1	4	-	1	2	
	Bulrush-type	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
	Cattail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	Dodder	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	
	Dodder, UNCH	-	-	-	-	-	-	-	-	-	-	-	2	1	-	2	1	
	Dropseed sandgrass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	Goosefoot	-	-	-	-	-	-	-	1	1	-	-	-	1	1	1	1	
	Grass Family	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Saltbush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Unidentified	-	-	-	-	-	-	-	1	1	-	-	-	1	2	-	3	1
	Unidentified, UNCH	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Other	Charcoal*	0	0	0	0	0	0.22	0.16	0.45	0.67	0.31	1.48	1.34	0.39	0.29	2.13	1.52	
	Bone*	0	0.06	<0.01	<0.01	<0.01	<0.01	0.11	0.16	0.23	0.64	0.51	1.67	4.33	4.88	0.45	4.93	6.82
	Fish vertebra	0	0	0	0	0	0	0	5	10	4	4	13	55	28	12	91	10
	Debitage	1	0	0	0	0	0	7	4	10	17	9	16	338	12	4	38	22

Note: Column Sample 17 was taken from within a krotovina. All seeds are charred unless indicated as uncharred (UNCH). Charcoal and bone are reported in weight (g).

APPENDIX B

CONNLEY CAVES COPROLITE COUNTS

The 2018 Technical Report by Paleosciences Archaeobotanical Series Team (PAST), LLC and the pollen and macrobotanical count data for the Connley Caves coprolites can be found at:

<https://link.springer.com/article/10.1007/s12520-019-00828-1#Sec23>

APPENDIX C

CODE FOR AGE DEPTH MODEL IN OXCAL

Plot(Paulina Marsh Core 2A)

```
{
  Outlier_Model("RSimple",N(0,100),0,"r");
  P_Sequence("Paulina Marsh Core 2A",1,0.5,U(-2,2))
  {
    Boundary(Core Bottom)
    {
      z=247;
    };
    R_Date("UGAMS- 38625",9000,25)
    {
      Outlier(.05);
      z=244;
    };
    R_Date("UGAMS- 40205",8400,20)
    {
      Outlier(.05);
      z=224;
    };
    R_Date("PSUAMS-8256",7690,30)
    {
      Outlier(.05);
      z=218;
    };
    Boundary("Unconformity")
    {
      z=217;
    };
    R_Date("UGAMS- 38626",2930,25)
    {
      Outlier(.05);
      z=199;
    };
    R_Date("PSUAMS-8255",2725,20)
    {
      Outlier(.05);
      z=135;
    };
    R_Date("UGAMS- 40204",2400,20)
    {
```

```
Outlier(.05);
z=111;
};
R_Date("PSUAMS-8106",1690,20)
{
  Outlier(.05);
  z=95;
};
R_Date("PSUAMS-8105",1235,25)
{
  Outlier(.05);
  z=60;
};
Boundary("Core Top")
{
  z=0.1;
};
};
};
};
```

APPENDIX D

POLLEN GRAIN AND TRACER SPORE ABSOLUTE COUNTS, TOTALS, AND POLLEN CONCENTRATION VALUES FOR
EACH PAUL-2A SAMPLE

Sample Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
<i>Abies</i>	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	1	0
Amaranthaceae	5	6	4	0	0	0	3	0	2	2	3	1	0	1	0	2	0
<i>Alnus</i>	0	2	1	0	0	11	3	0	1	2	0	3	0	2	0	3	3
Apiaceae	0	0	1	0	0	0	0	0	0	1	5	0	0	0	0	0	0
<i>Artemisia</i>	3	6	16	0	0	8	7	2	2	8	0	1	0	0	0	4	0
Asteraceae (dandelion-type)	0	2	2	0	0	0	1	1	0	1	0	0	0	0	0	0	0
Asteraceae (high spine)	5	11	8	0	1	9	4	3	10	6	7	3	0	6	0	12	0
Asteraceae (ragweed-type)	4	4	5	0	0	0	0	0	0	0	1	0	0	1	0	1	0
<i>Betula</i>	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Brassicaceae	15	12	7	0	0	17	11	3	9	14	9	3	0	13	0	6	0
cf. <i>Carya</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Caryophyllaceae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Convolvulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	0	6	0	0	0	26	30	1	5	15	37	14	0	81	0	64	4
Cupressaceae	0	0	0	0	0	2	1	0	0	2	0	0	0	0	0	5	0
<i>Eucalyptus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	0	0	0	0	0	1	0	0	2	2	1	0	0	9	0	0	0
Ferns (trilete spores)	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	0
<i>Galium</i>	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Iridaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	1	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0
Liliaceae cf. <i>Allium</i>	5	1	1	0	0	1	0	0	0	0	0	0	0	2	0	0	0
<i>Lotus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sample Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
<i>Nuphar</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pinus</i> (diploxylon)	60	31	75	0	1	50	39	0	59	66	33	6	1	51	0	59	8
<i>Pinus</i> (bladders)*	19	20	12	0	0	3	7	0	24	18	20	3.5	0	17	0	2	1
<i>Plantago</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	47	60	62	13	14	70	72	47	71	50	62	39	9	59	0	27	0
Polemoniaceae	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
<i>Polygala</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae cf. <i>Eriogonum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. <i>Polygonum</i>	6	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	0
<i>Potamogeton</i>	0	0	0	0	0	0	1	0	1	0	0	0	0	3	0	0	0
<i>Pseudotsuga</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quercus</i>	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0
Ranunculaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhamnaceae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Ribes</i>	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosaceae	0	0	0	0	0	1	2	1	2	2	0	0	0	0	0	3	0
<i>Rumex</i>	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Salix</i>	0	0	1	0	0	10	7	2	3	0	1	0	0	2	0	10	1
<i>Sagittaria</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sarcobatus</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Saxifragaceae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Solanaceae cf. <i>Solanum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trifolium</i> / <i>Melilotus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tsuga</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sample Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
<i>Typha latifolia</i>	0	1	0	0	1	0	0	0	7	11	9	0	0	7	0	0	0
<i>Vicia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	10	10	8	1	2	2	6	2	2	3	7	3	1	5	0	2	1
Degraded Indeterminate	30	25	16	4	0	3	1	2	3	10	5	3	0	4	0	2	3
Total	211	202	221	18	19	219	201	64	206	217	200	80.5	11	268	100	207	21
Lycopodium	186	172	83	168	103	83	24	100	35	148	74	100	100	82	0	93	100
PCV (per cc)	2192	2270	5147	207	356	5100	16190	1237	11378	2834	5224	1556	212	631	0	4302	406
	9	4	4	1	6	9	6	2	3	5	9	2	7	83		9	0

Sample Number	P18	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31
<i>Abies</i>	0	0	0	6	0	0	0	0	0	0	0	0	1
Amaranthaceae	0	0	3	0	2	1	0	0	4	2	1	0	8
<i>Alnus</i>	0	0	2	8	2	1	0	0	1	2	1	0	0
Apiaceae	0	0	0	13	0	0	0	0	5	10	0	0	2
<i>Artemisia</i>	0	0	5	6	7	6	1	0	0	1	2	34	4
Asteraceae (dandelion-type)	0	0	1	1	0	1	0	0	0	1	0	1	0
Asteraceae (high spine)	0	0	8	3	6	27	1	0	14	8	4	10	9
Asteraceae (ragweed-type)	0	0	0	0	0	2	0	0	3	0	1	0	0
<i>Betula</i>	0	0	0	*0	0	2	0	0	0	0	0	0	0
Brassicaceae	0	0	4	9	5	9	2	0	10	22	12	8	31
cf. <i>Carya</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0	0	0	0	3	3	16	1	0
<i>Convolvulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	3
Cyperaceae	0	0	75	108	96	87	0	0	27	34	6	4	15
Cupressaceae	0	0	1	4	0	0	0	0	0	0	0	1	0
<i>Eucalyptus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	0	0	10	0	6	6	0	0	5	0	15	6	30
Ferns (trilete spores)	0	0	0	2	1	0	0	0	0	0	0	0	0
<i>Galium</i>	0	0	0	1	0	0	0	0	0	0	0	0	0
Iridaceae	0	0	0	0	0	0	0	0	0	1	2	0	0
Lamiaceae	0	0	0	0	0	3	0	0	1	0	2	0	0
Liliaceae cf. <i>Allium</i>	0	0	3	3	0	0	0	0	0	0	0	0	0
<i>Lotus</i>	0	0	0	0	0	0	0	0	0	0	0	5	0

Sample Number	P18	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31
Malvaceae	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Nuphar</i>	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Pinus</i> (diploxylon)	0	0	58	59	45	37	0	0	16	35	15	18	7
<i>Pinus</i> (bladders)*	0	0	4	8	15	28	0	0	37	17	15	23	11
Plantago	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	0	0	26	12	66	23	0	0	97	40	80	108	56
Polemoniaceae	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Polygala</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae cf.													
<i>Eriogonum</i>	0	0	0	0	0	0	0	0	0	0	0	0	2
cf. <i>Polygonum</i>	0	0	0	0	0	3	0	0	0	0	0	0	1
<i>Potamogeton</i>	0	0	0	2	0	0	0	0	0	0	0	0	0
<i>Pseudotsuga</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quercus</i>	0	0	0	0	0	0	0	0	0	0	0	0	1
Ranunculaceae	0	0	0	1	0	0	0	0	0	0	0	0	0
Rhamnaceae	0	0	0	1	0	0	0	0	0	0	0	0	2
<i>Ribes</i>	0	0	0	0	0	0	0	0	0	2	0	0	0
Rosaceae	0	0	3	0	0	2	0	0	2	3	0	1	5
<i>Rumex</i>	0	0	2	0	0	0	0	0	0	0	0	0	0
<i>Salix</i>	0	0	7	10	9	24	0	0	0	0	2	0	1
<i>Sagittaria</i>	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Sarcobatus</i>	0	0	0	0	0	1	0	0	0	0	1	1	1
Saxifragaceae	0	0	0	0	0	0	0	0	0	2	0	0	0
Solanaceae cf.													
<i>Solanum</i>	0	0	0	0	0	0	16	0	0	0	0	0	1
<i>Trifolium/</i>													
<i>Melilotus</i>	0	0	0	0	0	0	0	0	0	15	17	0	0

Sample Number	P18	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31
<i>Tsuga</i>	0	0	1	1	0	0	0	0	0	0	0	1	0
<i>Typha latifolia</i>	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Vicia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	0	0	1	2	5	2	0	0	3	3	3	1	6
Degraded													
Indeterminate	0	0	1	0	1	2	0	0	5	1	8	6	1
Total	0	0	217	262	266	267	20	0	233	202	204	229	198
Lycopodium	100	50	14	25	72	114	100	100	40	86	118	86	63
PCV (per cc)	0	0	299646	202599	71421	45278	3866	0	112609	45408	33421	51477	64113

Sample Number	P32	P33	P34	P36	P37	P38	P39	P40	P41
Abies	0	0	0	0	0	0	0	1	1
Amaranthaceae	0	0	0	1	4	2	0	1	11
Alnus	0	0	0	0	3	3	3	1	0
Apiaceae	0	0	0	1	0	0	0	0	0
Artemisia	3	0	2	4	10	16	6	18	0
Asteraceae (dandelion-type)	0	2	0	2	7	6	3	1	2
Asteraceae (high spine)	3	6	0	5	33	47	8	19	9
Asteraceae (ragweed-type)	5	0	0	0	3	6	0	5	2
Betula	0	0	0	0	0	0	0	0	0
Brassicaceae	13	1	2	2	19	10	4	12	2
cf. Carya	0	0	0	0	0	0	0	0	0
Caryophyllaceae	0	0	0	0	0	0	0	1	0
Convolvulus	0	0	0	0	0	0	0	0	0
Cyperaceae	0	0	0	0	2	0	0	15	15
Cupressaceae	0	0	0	0	0	0	0	1	2
Eucalyptus	0	0	0	0	0	0	0	0	1
Fabaceae	3	12	0	0	1	0	0	0	0
Ferns (trilete spores)	0	0	0	0	0	0	2	1	0
Galium	0	0	0	0	0	0	0	0	2
Iridaceae	0	0	0	0	0	0	0	0	0
Lamiaceae	0	0	0	0	0	0	0	0	0
Liliaceae cf. Allium	0	0	0	0	0	0	1	1	0
Lotus	0	0	0	0	0	0	0	0	0

Sample Number	P32	P33	P34	P36	P37	P38	P39	P40	P41
Malvaceae	0	1	0	0	0	0	0	1	0
Nuphar	0	0	0	0	0	0	0	0	1
Pinus (diploxyton)	2	0	0	0	5	1	8	54	56
Pinus (bladders)*	1	0	0	1	8	6	5	11	4
Plantago	0	0	0	0	1	0	0	0	0
Poaceae	6	29	3	40	107	90	17	40	82
Polemoniaceae	0	0	0	0	0	0	0	0	0
<i>Polygala</i>	0	0	0	0	0	0	1	0	0
Polygonaceae cf. <i>Eriogonum</i>	0	0	0	0	0	0	0	0	0
cf. <i>Polygonum</i>	2	0	0	0	0	0	0	0	2
<i>Potamogeton</i>	0	0	0	0	0	0	0	0	0
<i>Pseudotsuga</i>	0	0	0	0	0	0	0	0	1
<i>Quercus</i>	0	0	0	0	0	0	0	0	1
Ranunculaceae	0	0	0	0	0	0	0	0	0
Rhamnaceae	0	0	0	0	0	0	0	0	0
<i>Ribes</i>	0	0	0	0	0	0	0	0	0
Rosaceae	0	0	0	0	1	0	0	0	0
<i>Rumex</i>	0	0	0	0	0	0	0	0	0
<i>Salix</i>	1	1	0	0	2	0	0	0	0
<i>Sagittaria</i>	0	0	0	0	0	0	0	0	0
<i>Sarcobatus</i>	0	0	0	0	0	0	0	0	0
Saxifragaceae	0	0	0	0	0	0	0	0	0

Sample Number	P32	P33	P34	P36	P37	P38	P39	P40	P41
<i>Solanaceae cf. Solanum</i>	0	0	0	0	0	0	0	0	0
<i>Trifolium/Melilotus</i>	0	0	0	0	0	0	0	0	0
<i>Tsuga</i>	0	0	0	0	0	0	0	1	0
<i>Typha latifolia</i>	0	0	0	0	0	0	1	0	1
<i>Vicia</i>	0	0	0	0	0	0	0	0	0
Unknown	1	0	0	0	8	1	0	2	5
Degraded									
Indeterminate	0	4	1	4	9	34	7	14	3
Total	40	56	8	60	223	222	66	200	203
Lycopodium	100	100	100	282	175	52	226	14	34
PCV (per cc)	7733	10826	1547	4113	24634	82533	5646	276171	115423

*Bladder counts were adjusted so that two bladders equal one “*Pinus* (bladder)” pollen grain count.