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The Younger Dryas climatic event is a global phenomenon associated with a 1,000 year return to glacial conditions during the late Pleistocene period between 12,800 and 11,500 cal BP. Because of its significant effects on paleoenvironmental conditions in some parts of the world, archaeologists commonly seek to assess whether the Younger Dryas climatic event had any measureable influence on prehistoric human societies. The early, well preserved archaeological and paleoenvironmental records held in the Paisley Caves site of Oregon's Northern Great Basin provide an opportunity to examine questions human-environmental interaction at the end of the Pleistocene Epoch. Based on a study of pollen records and artifact frequency in the site's Cave 2 deposits, this thesis reports a positive relationship between artifact deposition and marsh expansion in the Summer Lake sub- basin during the Younger Dryas chronozone. While not indicative of a major change in early forager cultural patterns in the Northern Great Basin, these results provide an important perspective on early settlement patterns and human ecology in the far western region of North America.

Palynological Perspectives on Younger Dryas to Early Holocene Human Ecology at Paisley Caves, Oregon

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Chantel V. Saban, Author

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Chapter 1: Introduction

Introduction

The Younger Dryas was a cooling event marked by a two to three degree Celsius drop in global temperatures between 12,800 and 11,500 cal BP (Berger 1990; Mayewski et al. 1993; Taylor et al. 1997; Gulliksen et al. 1998; Alley 2000; Carlson 2013). Various parts of the world experienced the cooling effects by different amounts (Peteet 1995: 1360; Carlson 2013), but the cooling primarily impacted the Northern Hemisphere (Clark et al. 2002: 866; Shakun and Carlson 2010: 1801–1802, 1814; Carlson 2013: 126–131). The Younger Dryas affected the northeastern and central regions of North America significantly (Ellis et al. 2011; Newby et al. 2005; Anderson 1997; Allen and Anderson 1993) and studies show that it had variable effects west of the Rocky Mountains (Mathewes et al. 1993; Briggs et al. 2005; Vacco et al. 2005; Huckleberry and Fadem 2007; Goebel et al. 2011; Reeder et al. 2011; Oviatt et al. 2003). In the Pacific Northwest Coast region, paleobotanical records reflect precipitation increases and, in some places, periods of glacial advance (Mathewes 1993; Mathewes et al. 1993; Bevis 1995; Pellatt et al. 2002; Fedje et al. 2011). Speleothem research from the Oregon Caves also showed an increase in precipitation during the Younger Drays (Vacco et al. 2005), while marked climate events are reported from moraine research in the Siskiyous and Aspen Butte, Oregon (Bevis 1995: 25–30, 95–102) and by mapping air mass flow variability off the Pacific (Mitchell 1976: 921).

Archaeological sites are often excellent sources of prehistoric environmental data and their study enhances understanding of associated records of human behavior (Mehringer and Haynes 1965; Bettinger 1978; Bryant and Holloway 1983; Dolukhanov 1997; Fitzhugh et al. 2002; Kelly 2007: 35–37; Meltzer and Holliday 2010; Munoz et al. 2010; Fedje et al. 2011; Lee 2011; Reeder et al. 2011; Domingo et al. 2013). In an attempt to establish meaningful interpretations between the artifact record and the environmental conditions they were deposited under, anthropologist Julian Steward developed the theoretical framework of cultural ecology (Steward 1955). While early models showed significant weaknesses towards establishing clear relationships between societies, technology and environments (Harris 1968: 668; Kelly 2007:42–44), the development of Cultural Ecology and its offshoots including Human Behavioral Ecology, are helpful frameworks in studying past cultures within the resource constraints and opportunities available that foragers experienced. While climate and ecology are not the only phenomena that drive cultural decision making (Kelly 2007: 36, 39, 337), climatic changes offer measurable opportunities to comparing changes in the archaeological record to changes in past environments. Identifying past cultural behaviors directly within the context of their distinct regional environments enables more accurate interpretations of past forager behaviors and is a common research goal for archaeologists (Bettinger 1993; Pearsall 2001: 2; Goebel et al. 2011; Holdaway et al. 2010). By reconstructing paleoenvironments in direct association to archaeological sites, researchers can recreate how prehistoric people may have responded to ecological changes. Archaeologists are interested to know if the Younger Dryas climate event had any effect on prehistoric human societies and typically do so by examining contemporaneous records of paleoenvironmental condition and cultural behavior reflected in archaeological artifacts and environmental interaction.

With the presence of well-preserved sediments, pollen analysis offers a reliable method of environmental reconstruction (Pearsall 2001: 245–246). Examples of pollen use in conjunction with archaeological research includes pollen cores from Southwest Asia that indicated forests gave way to open steppe conditions in response to drier conditions during the Younger Dryas (Moore and Hillman 1992; Carlson 2013: 126–128). The cultural response to the increase in aridity was an increase in sedentary behaviors as hunter-gatherers altered foraging strategies to cope with a reduced carrying capacity of their environments. These new strategies eventually resulted in the advent of domestication in that part of the world, which includes some of the oldest permanent settlements in human history (Moore and Hillman 1992: 490; Colledge et al. 2007: 21–34). The Younger Dryas period also saw similar cultural responses occur in parts of Northeast Asia (Lee et al. 2007; Lee and Bestel 2007) and Mesoamerica (Metcalfe et al. 2000; Cowan et al. 2006; Hastorf 2009). However, not all cultures found it necessary to dramatically alter foraging strategies to cope with reductions in subsistence resources, as the carrying capacities of some environments may have increased instead of diminished during the Younger Dryas.

Prehistoric foragers in North America undoubtedly would have noticed the climatic changes of the Younger Dryas, although by varying amounts (Meltzer and Holliday 2010; Goebel et al. 2011; Carlson 2013). The end of the Pleistocene saw the extinction of 35 genera of mammals in North America, 19 genera of birds (Faith and Surovell 2009; Grayson 2011b: 176–181) and the spruce *Picea critchfieldii* (Jackson and Weng 1999; Jackson and Overpeck 2000: 210). The short-lived Clovis and later Folsom points–technological phenomena primarily of central and eastern North America–may have reflected probable indicators of cultural responses to climate change. Both tool types disappear entirely from the archaeological record by the end of the Pleistocene and can generally be considered tool types unique to the Younger Dryas (Kelly and Todd 1988; Anderson and Gillam 2000: 19; Waters and Stafford 2007; Beck and Jones 2010: 82; Meltzer 2010: 202, 254–255; Grayson 2011: 57; 1993: 236). Despite these events, Meltzer and Holliday (2010: 2) argue that the Younger Dryas cooling period did not trigger widespread adaptive change that can be measured in archaeological patterns of early North American sites. The authors contend that reconstructions of severe and abrupt Younger Dryas period climate change is based more on more distant Greenlandic ice core data and not clearly reflected in regional paleoclimate information that fails to show such dramatic environmental change.

Metin Eren (2009) examined sixty Paleoindian sites around the Great Lakes region and used pollen to identify how regional ecological changes from the Younger Dryas may have contributed to visible cultural adaptations. His results showed a lack of significant changes in Paleoindian technological adaptations, which he interpreted as significant as it is generally thought that changes in technology are automatic indicators of cultural adaptations to changing environments. In contrast, the Debra Friedkin archaeological site in Midland, Texas is reported to show a significant shift in Paleoindian stone tool technology corresponding with Clovis technology shifting to Folsom/Midland points shortly after the onset of the Younger Dryas (Jennings 2012: 32–39) that triggered a rapid change in paleoecology. Despite this rapid change, it does not appear that the changes in technology were due to negative impacts of the Younger Dryas cooling, at least, as much of that as can be determined by stone tools. As Meltzer and Holliday (2010) point out, major cultural adaptations occurred at many times following the Younger Dryas period in association with less significant environmental changes (2010: 31). Meltzer and Holliday further state that the cooling effects of the Younger Dryas was even less punctuated ecologically in the Rocky Mountains and Central Plains regions than they were on the East coast of North America (2010: 4, 14-20, 30). Metin Eren (2012) issued a challenge to those studying the Younger Dryas to, “follow a logical and rigorous framework in order to prove direct causal relationship between climate change and changes in ‘culture’” with the requirements being that there must be evidence of both environmental and cultural changes that are well correlated (Meltzer and Bar-Yosef 2012: 241). In order to meet this challenge, we must find and study contemporaneous archaeological and paleoenvironmental records from sites that span the Younger Dryas chronozone. Such a record exists at the Paisley Caves site in Oregon's Northern Great Basin region.

Research in the Pacific Northwest region of North America, including the Northern Great Basin where the Paisley Caves are located, indicates a marked increase in precipitation during the Younger Dryas (Mitchell 1976; Mathewes et al 1993; Sea and Whitlock 1995; Kienast and McKay 2001; Friele and Clague 2002; Barron et al. 2003; Vacco et al. 2005; MacDonald et al. 2008; Kaufman et al. 2010; Goebel et al. 2011: 483; Reeder et al. 2011; Carlson 2013: 126). Beginning with Ernst Antevs in the 1930s, much work has been accomplished toward reconstructing paleoenvironments in the Northern Great Basin. Many researchers have used pack rat middens to extract records of past climate and vegetation patterns as pollen cores can be difficult to obtain due to the rather ephemeral nature of Great Basin lakes (D'Azevedo et al. 1986: 31–50; Wigand 1987; Grayson 1993: 118, 197, 2011: 136–141, 143). Located in the rainshadow of the Cascade Range, the Northern Great Basin is ecologically sensitive to any changes in precipitation input, and the arid conditions allow for excellent preservation of many types of environmental and archaeological materials (Grayson 2011: 11-12).

Archaeological investigations at the Paisley Caves site has produced evidence of human occupation spanning at least 14,500 years (Gilbert et al. 2008; Aikens et al. 2011: 49–54; Grayson 2011: 61–65). The artifacts recovered there are primarily organic in nature, such as coprolites, bones and fiber artifacts, as opposed to other late Pleistocene-aged sites that typically include larger quantities of stone tools and debitage. Excavations at Paisley Caves resulted in the discovery of an unusually dense cultural deposit known as the Botanical Lens, which was radiometrically dated to the Younger Dryas period (Jenkins et al. 2013b: 4; Jenkins 2013c: 496). If paleoenvironmental changes caused by Younger Dryas climate conditions affected forager decision-making at sites in the Northern Great Basin then we should be able to measure this pattern from the archaeological record of sites like Paisley Caves.

Research Question

This thesis examines the question of whether climatic changes during the Younger Dryas chronozone measurably correspond to changes in cultural activity recorded at the Paisley Caves site. Answering this question requires knowledge of what paleoenvironmental patterns in the Summer Lake sub- basin were like before, during and after the Younger Dryas chronozone and how these patterns correspond to archaeological evidence of human behaviors.

Paleoenvironmental and archaeological patterns will be deduced from a palynological study of the site's Cave 2, Unit 6 deposits, which provide a view of vegetative populations and, by extension, paleoclimate conditions, and a parallel comparison of contemporaneous artifact frequencies, which are taken to represent a proxy measure for the relative intensity of site use through time. Special emphasis will be placed on mesic plant communities for the purpose of providing measurable environmental materials to compare against artifact counts. Mesic plants generally represent moist ecological conditions, and are described in greater detail in chapter 5.

Organization of Thesis

This thesis evaluates whether a significant relationship can be seen between cultural materials recovered from Paisley Caves and distinct ecological conditions triggered by the Younger Dryas climatic event. To do so, this study is organized in the following way: Chapter 2 examines the geologic, geographic, and limnological history of the Paisley Caves site and region, followed by a brief description of Paisley Cave 2 sediments, and description of the Younger Dryas period and its associated artifact assemblage, the Botanical Lens. The floristic history of the Northern Great Basin region and review of previous related studies is also presented in Chapter 2. Chapter 3 describes the methods used to describe, date and interpret pollen results. Chapter 4 discusses the results of analysis and describes the distinct Pollen Zones identified. Chapter 5 discusses the significance of mesic plant ecologies as identified through the pollen and compares the pollen results to the archaeological record of Cave 2 and considers the question of human-environmental interaction in the Summer Lake sub- basin during the Younger Dryas.

Chapter 2: Background

Previous Research

Measuring pollen percentage changes is commonly used to model paleoenvironmental conditions (Bryant and Holloway 1983; Pearsall 2001: 245) by showing plant taxa fluctuations over time (Newby et al. 2000; Peteet 2000; Shuman et al. 2001, 2002: 1803). Wet lake cores are typically preferred for this due to ideal preservation of the pollen rain over time. However, despite the presence of a large lakebed at Paisley, there is a palynological time-gap within the Summer Lake sub- basin that spans from approximately 16,000 years ago to the present (Grayson 1993: 118). The gap is due to occasional desiccation of Summer Lake. This occasional desiccation of remaining saline lakes in the Northern Great Basin region (Grayson 1993: 117–118) is common and results in deflation of lake sediments due to aeolian erosion (Hershler et al. 2002: 31; Negrini et al. 2000). Geological research in the Summer Lake basin revealed the presence of a large freshwater system, which is known as pluvial Lake Chewaucan. Over the last seventy years, the Chewaucan Basin has been the focus of several paleoecological research projects, beginning with geologist and varve specialist Ernst Antevs (1938). Antevs' primary focus was attempting to date Lake Chewaucan's limnological history and prehistoric precipitation rates. A decade later, Henry Hansen sampled sediments from three localities in and near Chewaucan Marsh (1947) in an attempt to rebuild the paleoenvironment of the area. Hansen's study lacked a more in-depth description of plant variation over time and focused primarily on conifer presence with minimal attention given to grasses and chenopods. The study also lacked a reliable chronology beyond the identification of Mazama tephra in the sediment core. However the work did provide an excellent baseline structure of what to expect floristically in the Paisley pollen assemblage.

In 1953, Clarence Conrad described the complex sedimentary structure found in the exposed Ana River bluffs of north Summer Lake, while S.G. Brown (1957) studied the groundwater hydrology of the Ana River Springs and its effects on the water levels of Summer Lake. In 1975, Van Denburgh described the recent history of hydrology and geochronology of Summer Lake, specifically describing fluctuating water and salinity inputs. Of particular interest to this study was Van Denburgh's argument that due to groundwater input during the late Pleistocene, Winter Lake, the freshwater predecessor to Summer Lake, should have remained a higher and more stable body of water than Lake Abert to the east, with a much lower mineral input, but that the reverse that occurred was likely due to fault shifts (1975: C2). Dorothy Freidel later revisited this in 2001 where she discusses lake-level oscillations of Lake Chewaucan and ground-water input from Fort Rock Basin (Figure 1.1) (Friedel 1994; Negrini et al. 2001: DF 1).

Botanist Arthur Cronquist and others (1972) compiled the *Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A.* series for the New York Botanical Garden. The seven volume series begins with a thorough description of the geologic and floristic history of the Great Basin that then moves into family descriptions and dichotomous identification keys for plants found throughout the Great Basin; volume one details endemic plant locations of the Great Basin, as well as descriptions of multiple floristic subdivisions. Cronquist's work on Great Basin flora remains one of the best resources for understanding floristic distribution and variety within the Great Basin, as well as what geological and climatic factors contribute to plant presence. Peter Mehringer analyzed palynological samples from throughout the Great Basin. His closest work to the Chewaucan Basin was 96 kilometers north in the Fort Rock Basin (Figure 1.1) and 160 kilometers east in the Catlow Valley and Steens Mountain (Figure 1.1). Focusing on analysis between grass and sagebrush pollen, the pollen combined with sediment analysis resulted in Mehringer stating that the Great Basin was subject to "short, sharp climatic shifts" during the late

Pleistocene through the mid Holocene (Mehringer and Wigand 1986; Mehringer and Cannon 1994: 321; Grayson 2011: 253, 285).

Ira Allison (1982) explored the details of pluvial Lake Chewaucan and the histories of the smaller sub- basins. Allison’s work has remained one of the most complete studies of the Chewaucan hydrological and geological systems and tied together all works previous to the 1980s from the area. Other foundational works from the 1980s include Jonathan Davis and his chronological sequencing of tephra layers observed in north Summer Lake sub- basin Ana River sediment deposits (Davis 1985). Further lithostratigraphic analyses were performed in the 1990s by Daniel B. Erbes, but with greater emphasis on sedimentation in relation to past climate change (1996). Donald Grayson’s *Desert’s Past: A Prehistory of the Great Basin* (1993) discusses previous ecological, ethnographic and archaeological studies of the Chewaucan Basin and the Great Basin as a whole in a succinct format. Grayson’s follow-up publication entitled *The Great Basin: A Natural Prehistory of the Great Basin* (2011) provides updated research results since 1993.

Robert Negrini (2000) measured magnetic fluctuations and pollen records in Lake Chewaucan sediments from three cores taken on the north, west and south portions of Summer Lake, producing a record of paleoclimate constants in the Basin over a 250,000-year period. The two-part report included a discussion of palynological results. The report did not include palynological data from the last 16,000 years, presumably due to lake desiccation resulting in the loss of the pollen record through aeolian erosion as mentioned by Grayson (1993: 118) Negrini (2001) and Hershler (2002). A significant portion of this missing pollen interval survived in Paisley Caves.

Silvio Pezzopane (2001) followed up Negrini by mapping stable Chewaucan high-stands and correlating to elevations established by Allison (Figure 2.1). Pezzopane’s map and related dates to lake surface elevations of Summer Lake show how much lake shore was dry during the target time period of this thesis, a crucial component when considering what areas plants were growing on in relation to Winter Lake, the old course of the Chewaucan River and the caves. Paleoenvironmental records of pluvial Lake Chewaucan's condition and associated vegetation populations that would typically be held in its lacustrine sediments are unfortunately incomplete as erosion appears to have removed sediments younger than 16,000 years BP. In contrast, Paisley Cave sediments were apparently more protected from the effects of weathering and cover a large portion of this palynological gap otherwise absent from Summer Lake, yet in the same way reflect the ambient floristic conditions present in the Summer Lake basin through time. Caves are excellent repositories for pollen accumulation over long periods of time, particularly in arid areas with good sedimentation rates, such as observed in the Northern Great Basin (Davis 1963, 1990; Navarro et al. 2001). Much is understood about the Paisley Caves site formation and taphonomy (Jenkins et al. 2012) but detailed climate and environment records are not yet available.

Palynological studies from the Great Basin beyond the Chewaucan Basin that span the period between 16,000 years ago and today are relatively rare due to similar aeolian erosion of other desiccated lake beds; however, pollen has been recovered from the remains of Lake Bonneville in Utah (Louderback and Rhode 2009; Oviatt et al. 2003), within coprolites recovered from Hidden Cave, Nevada (Rhode 2003), Pyramid Lake, Nevada (Briggs et al. 2005) and Owens Lake in California (Bettinger 1977; Litwin et al. 1997). All of those are far to the east or south of the Chewaucan Basin and in different ecological, precipitation and aridity zones as compared to the Summer Lake basin (Thorson et al. 2003). All show significant precipitation increase and marsh expansions as seen by the presence of marsh plant pollen. Additional regional palynological work was done by Peter Wigand (1987) at Diamond Pond, Harney

County (Figure 1.1), where Wigand describes paleoenvironmental conditions for the last 6,000 years. Cores were also taken from Wildhorse and Fish Lakes on Steens Mountain (Figure 1.1) (Bryant 1985: 167–189), which showed that ice-free conditions were present by 9,500 cal BP, with cool and moist early Holocene conditions followed by a long period of increasing aridity, mirroring Hansen’s (1947) pollen results from Chewaucan Marsh.

Younger Dryas Chronozone

The Younger Dryas chronozone, a punctuated cooling event that resulted in portions of the Northern Hemisphere returning to near-glacial conditions (Alley 2000: 222; Grove 2004: 536–544; Carlson 2013: 130) and lasted a 1,300 year period between approximately 12,800 to 11,500 calendar years before present (Figure 2.2) (Dolukhanov 1997: 183, 184; Alley 2000; Yu and Wright Jr. 2001: 334; Lowell and Kelly 2008: 348; Carlson 2013). Chronozones are periods of time that begin at distinct and sudden identifiable events that are observable in the palynological, geologic, or fossil record (Peteet 1995: 93). The Younger Dryas chronozone is defined by a rapid cooling at its onset followed by a warming marking the end of the Pleistocene and the onset of the Holocene (Taylor et al. 1997: 825; Gulliksen et al. 1998: 249, 256)**.**

The Younger Dryas chronozone was first identified in Denmark and named after the flower genus *Dryas octopetala* L. (Carlson 2013: 126). Native to the arctic and alpine regions of Europe, Asia and North America, *Dryas octopetala* appeared abruptly south of the Arctic region in lake-core pollen, indicating the replacement of forests in Scandinavia by glacial tundra (Carlson 2013: 126). Studies in the Colorado Rockies show evidence of rapid conifer response to the sudden cooling then warming oscillations (Reasoner and Jodry 2000). Further, substantial evidence shows that the Younger Dryas cooling effects were more punctuated and greater in intensity east of the Rockies (Ellis et al. 2011; Yu and Wright Jr. 2001; Jackson and Weng 1999). The effects of the Younger Dryas in the Pacific Northwestern region of North America was a reduction in sea surface temperatures and a moderate increase in storm activity and precipitation (Vacco et al. 2005: 253; Kiefer and Kienast 2005: 1064, 1067; Bevis 1995; Mitchell 1976).

Geography, Geology and Lake History

The name ‘Chewaucan’ is derived from the Klamath word ‘tchua’ meaning wapato (*Sagittaria* sp. L.) and the suffix ‘-keni’ meaning place or locality (Allison 1982: 14). Pluvial Lake Chewaucan filled the Chewaucan Basin 18,000 years ago at a maximum depth of approximately 114.3 meters, covered an area of 1,243 km^2 and reached a pluvial maximum elevation of 1,378 MASL (Grayson 1993: 98; Negrini et al. 2000: 154). Water levels began falling between 17,000 and 18,000 years ago, resulting in the Summer Lake sub- basin becoming hydrologically separated from the rest of the Chewaucan basin (Licciardi 2001: 114; Negrini et al. 2001; Jenkins et al. 2004: 10). ‘Pluvial’ describes lakes with high water levels because of altered ratios between precipitation and evaporation (Grayson 2011: 93). During the late Pleistocene, precipitation rates were higher than evaporation rates, so inland lakes could sustain high levels of freshwater stands (Negrini et al. 2001: 71). This ratio switched dramatically during the early to mid- Holocene when evaporation rates exceeded precipitation rates (Grayson 1993: 98, 2011: 93–94), resulting in lake desiccation and increased salinity.

Ira Allison made a name distinction regarding the current Summer Lake (1982: 38). He referred to the fresh water, hydrologically independent lake (i.e. not hydrologically connected to the rest of the Chewaucan Basin) as Winter Lake, and the current saline lake as Summer Lake. The hydrologically connected pluvial lake of the other three sub- basins (Lake Abert, and North and South Marshes) during the Pleistocene Allison named ZX Lake. This paper follows Allison’s name distinction with Winter Lake being fresh water lake and Summer Lake being the current saline lake. All the lakes within the Northern Great Basin are endorheic bodies of water and have no outlets to the ocean. The hydrological boundary of the Great Basin includes all bodies of water that do not drain to the Pacific and water loss occurs primarily through evaporation.

The northern Great Basin region is dominated by fault- block mountains that trend north-northwest. The basins that contained Pleistocene-aged pluvial lakes are low- lying grabens situated between these fault block mountains. The fault- block mountains bounding the basins are generally defined by a gentle sloping side uplifted and ending abruptly in steep escarpments (Allison 1982: 15; Pezzopane and Weldon 1993: 1145, 1152). The Chewaucan Basin is located in the northern extreme of the North American Great Basin and is geographically characterized by closed basins surrounded by terraces formed by prehistoric lakes and interspersed by hills, basaltic ridges, and fault block mountains (Gilbert et al. 2008). The Paisley Caves are located in the Chewaucan Basin.

The v- shaped Chewaucan Basin is a composite basin made up of four sub- basins: Lake Abert in the northeast portion, Upper and Lower Chewaucan marshes in the south, and Summer Lake in the northwest (Figure 1.2). Of the four sub- basins, the Summer Lake sub- basin is the most northerly and the lowest of the depressions a floor elevation of 1,265 MASL (Hershler et al. 2002: 32; Negrini et al. 2001: 12; Allison 1982). The Summer Lake sub- basin is bordered on the west by the steep fault scarp of Winter Rim elevation 2,073 MASL with the Fremont National Forest directly up to the abrupt edge of Winter Rim. Paleoenvironmental records of pluvial Lake Chewaucan's condition and associated vegetation populations that would typically be held in its lacustrine sediments are unfortunately incomplete as aeolian erosion has removed sediments younger than 16,000 years BP. In contrast, Paisley Cave sediments were more protected from the effects of weathering and contain a large portion of the palynological gap otherwise absent from Summer Lake. Caves are excellent repositories for pollen accumulation over long periods of time, particularly in arid areas with good sedimentation rates, such as observed in the Northern Great Basin (Davis 1963, 1990; Navarro et al. 2001). Much is understood about the Paisley

Caves site formation and taphonomy (Jenkins et al. 2012) but detailed climate and environment records are not yet available.

The Paisley Caves are located toward the southeast edge of Summer Lake sub- basin on a west facing, Miocene-aged ridge of scoracious rhyolitic basalt (Figure 2.3 and 2.4). Rock falls during earthquakes are common and there are two earthquakes sources, including the Slide Mountain-Winter Rim Fault that runs along the base of Winter Rim and can produce magnitude-7 earthquakes (Pezzopane and Weldon 1993: 1148; Allison 1982: 15), and the Ana River Fault (also called the Klippel Point Fault) which trends east to west at the northern terminus of the Summer Lake sub- basin (Negrini et al. 2001: 13). Rapid landform transformation due to tectonic activity can be observed at Slide Mountain, located at the southern terminus of Summer Lake sub- basin at Winter Rim (Figure 1.2). It was in this area that sometime between 2,000 and 1,500 years ago an earthquake a massive landslide. The same earthquake may have also triggered the collapse of the front of the Cave 2 ceiling that currently appears as a boulder atop the Cave 2 sediment profile. The boulder appears as a large tan ‘island’ in Figure 2.5 (Dennis L. Jenkins, personal communication, May 2014).

Floristic History of Northern Great Basin

The presence of well-preserved and largely well- structured stratigraphic sequences held in dry caves and rockshelters of the northern Great Basin provide excellent repositories for studying ancient environments. Geographically the area is designated as a High Desert ecological province (Figure 2.6) based on its distinct combinations of geological features, geomorphology and climate (Anderson et al. 1998: 1, 3). The Great Basin as a whole can be delineated floristically as well as hydrologically (Figure 2.7) (Cronquist et al. 1972; Grayson 1993: 21) with the Northern Great Basin distinct from southern regions due primarily to higher precipitation and lower evaporation rates (Grayson 1993: 83). Cronquist subdivided the Great Basin and designated the extreme northwest extent as being within the Great Basin Division, Lake Section (1972: 78, 82, 85–87). The plants that define Northern Great Basin plant communities include *Artemesia* or *Atriplex* in lower elevations, and *Juniperus* or *Pinus* in higher elevations above 1,524 MASL (D’Azevedo et al. 1986; Grayson 1993: 21). The distinct differences in shrub and tree dominance are due to temperature declination and precipitation increases at higher elevations (D’Azevedo et al. 1986: 51, 55). Ecological provinces possess a distinct combination of geological and geomorphological features, resulting in regional vegetation complexes dominating relative to geology, geomorphology, and climate (Anderson et al. 1998: 1).

Northern Great Basin plants that were present in the late Pleistocene and early Holocene still remain with the primary difference that many species are now at different elevations or moved to other areas (Cronquist et al. 1972: 36; D’Azevedo et al. 1986: 44–50; Grayson 1993: 139, 143–150; Cohen et al. 2000: 170). Evidence of late Pleistocene and early Holocene Northern Great Basin vegetation has come from studying pack rat middens (Grayson 1993: 117), macrobotanical materials recovered from archaeological sites (Hansen 1947; Elsasser 1981;

Beck and Jones 1997; Cummings and Puseman 2003; Minckley et al. 2007; Louderback and Rhode 2009), microbotanical materials such as pollen and starch residues (D’Azevedo et al. 1986: 44–50; Wigand 1987; Cohen et al. 2000: 170) and isotope analysis of lake sediments (Negrini et al. 2000: 137–139; Licciardi 2001).

Palynological analysis focusing on late Pleistocene to early Holocene environments have been previously conducted in several areas of the Great Basin (Beck and Jones 1997: 173–174, 214–215), including from Summer Lake itself (Cohen et al. 2000), Diamond Ponds, Oregon (Wigand 1987), Tulare Lake in California (Davis 1999), Hidden Cave in Nevada (Rhode 2003), the Bonneville Basin in Utah (Louderback and Rhode 2009) and locations in the southwest. Most palynologists prefer to sample cores from lakes that have been wet the entirety of their target time period as water protects sediments from erosion or weathering and results in an unbroken pollen sequence (Pearsall 2001: 245) that provides a regional perspective versus a highly localized view one gets using pack-rat or grindstone acquired data. Over the last 1,000 years, Summer Lake has completely desiccated several times, resulting in aeolian erosion of its exposed lake deposits (Grayson 1993: 117). For this reason, the last 16,000 years of stratigraphic time is missing from the lake’s deposits, requiring another kind of pollen record to reveal local vegetative conditions at the late Pleistocene- early Holocene period.

Paisley Caves Site Description

The Paisley Caves are composed of eight caves on a west facing ridge of scoracious basalt cut by wave action of pluvial Lake Chewaucan during the Pleistocene and sit at an average elevation of approximately 1377.70 MASL. Each cave is numbered towards the north with Cave 1 being the furthest south. This study focuses on the record from Cave 2 only. Cave 2 measures approximately seven meters long by six meters wide with a large boulder, originally the cave roof, sitting at the west- facing entrance. Beginning in 2002 University of Oregon field school excavations led by Dennis Jenkins excavated to a depth of 240 centimeters in Cave 2. Sediments used for this study were taken from the southern wall created by previous excavations of Cave 2 in unit 6B (Figure 1.3 and 2.5). Approximately 90 cm below datum, at an elevation of 1365.65 MASL was a dense cultural deposit referred to as the Botanical Lens due to the associated presence of shredded sagebrush bark strips found throughout the deposit (Jenkins et al. 2013b: 10).

Paisley Cave 2 Sediments

To measure how percentages of pollen taxa have shifted over time, identified pollen grains were counted from levels where they were collected, preserving their chronological sequence. Sample levels assigned age ranges using radiocarbon dated (^{14}C) materials recovered from corresponding sedimentary layers. The ages used in this study include previously obtained ^{14}C ages as well as two more recent ^{14}C ages obtained directly from Cave 2, Unit 6, Quad B (2/6B) (Table 1). Dates were assigned to stratigraphic elevations using ^{14}C ages from units adjacent to 2/6B. Two ^{14}C ages were obtained in 2013 from 2/6B to fill in part of a date gap. Table 1 illustrates stratigraphic elevations and their calibrated ages obtained from ^{14}C samples. Actual ages are shown in bold, while date gaps shown italicized are averages between known ages.

Sediment samples taken in 2012 for this analysis were taken at 5 cm intervals, beginning at the base of the Mazama tephra layer down to level 21. Pre- Mazama sediment deposits accumulate at approximately 1 cm per 44 to 80 years (Jenkins et al. 2012a: 224; Jenkins 2013c: 504). The Mazama deposits are the tephra and ash layer deposited by the eruption of Mount Mazama (Figure 11) 7,600 cal BP years ago (Bacon 1983).

The pre- Mazama sediments of Cave 2 are well stratified, polygenetic and complex in origin. Lithostratigraphic units (LUs) are the distinct sediment types that comprise the matrices of the units and are defined by their sediment characteristics and not by age (Gasche and Tunca 1983: 328; Stein 1987: 347). There are seven LUs found within Paisley Caves 2 (Figure 2.8). LU1 to LU3 comprise the sediment types extending from bedrock up to the eruption of Mount Mazama. Mazama tephra is LU4 and the modern day sample included in this report is LU7 (Jenkins et al. 2012: 227). LU1 sediments were not sampled for this thesis analysis. LU2 sits directly on bedrock in the southeast portion of Cave 2 in unit 2/6A, but not in section 2/6B. Instead 2/6B sits on top of LU1 sediments.

The oldest portion of the pollen assemblage (Pollen Zone 1) is entirely contained within LU2 sediments, which are described as poorly sorted, sandy loam (Jenkins et al. 2012: 227). A mixing of LU2 and LU3 occurs at level 17, approximately 12,569 cal BP (Table 1). LU3 is a mix of fine aeolian deposited sediments, some smaller gravels mixed with highly angular roof fall, and heavy organic components of plant materials and bat guano (Jenkins et al. 2012: 227) indicating changes to sediment input. The sediments are cemented by urine, occasionally resulting in an indurated matrix. LU3 sediments are firm to hard with abundant macrobotanical content, amorphous organics and trace gravels as well as high amounts of *Neotoma* and *Chiroptera* feces (Jenkins et al. 2012: 224).

Prehistory and the Paisley Caves 2 Artifact Assemblage

The Chewaucan basin contains numerous prehistoric sites in addition to the Paisley Caves, including mid to late Holocene house aged pits located on ZX Ranch property in Upper Chewaucan Marsh (Oetting 1990: 103), house rings and pits along the east side of Lake Abert (Aikens et al. 2011: 114–116), and dozens of pictographs and petroglyphs scattered throughout the Basin as well as the drainages of the Chewaucan River and Willow Creek (Figure 1.2). Based on changes of cultural indicators that include localities and artifacts, occupations of the Chewaucan Basin and the Northern Great Basin as a whole are divided into five culture periods (Jenkins et al. 2004: 7–16). These include the Paisley Period (16,000 to 12,000 years cal BP), the Fort Rock Period (12,000-9,500 cal BP), The Lunette Lake Period (9,500-6,000 cal BP), the Bergen Period (6,000-2,500 cal BP) and the Boulder Village Period (2,500-100 cal BP) (Jenkins et al. 2004). Currently only the Paisley Caves have yielded cultural materials directly associated to the Paisley Period, including Western Stemmed Tradition projectile points, cordage, and human coprolites). Human coprolites were dated to approximately 14,300 cal BP (Gilbert et al. 2008).

The Fort Rock Period includes most of the Younger Dryas chronozone, and is based on Clovis artifacts recovered from the Dietz site and other isolated localities, and extends into the early Holocene. This period is notable for winter habitation of caves and rockshelters around pluvial lakes, (Jenkins et al. 2004: 11–12). Artifacts notable for this time period include Western Stemmed Tradition projectile points, lithic crescents, Fort Rock style sandals and undecorated twine basketry. The final period that will be mentioned here is the Lunette Lake Period, which spans the early Holocene through the eruption of Mount Mazama at approximately 7,600 cal BP (Jenkins et al. 2004: 12–16). This was a very dry period punctuated by wet intervals, with sites composed primarily of temporary hunting and foraging camps located on the edges of permanent lakes and intermittent or seasonal lakes and ponds. A notable example comes from the Component 3 site at Paulina Lake, which showed a less diverse tool assemblage than previous periods.

This study analyzes materials recovered from Paisley Cave 2 that span approximately a six thousand year period between 7,600 cal BP to 13,689 cal BP. In addition to human coprolites and cultural artifacts, an abundance of organic artifacts including plants, bones, shell, and non-human coprolites were also recovered. Basketry and cordage recovered yielded little in terms of culturally diagnostic information on early people (Thomas J. Connolly, personal communication, March 2013) and Western Stemmed Tradition (WST) projectile point fragments were recovered from some of the oldest stratigraphic levels at Paisley (Jenkins et al. 2012: 224). The WST projectile points are technologically and stylistically distinct from Clovis points (Jenkins et al. 2013b, 2012a; Aikens et al. 2011: 42–45; Beck and Jones 2010). In relation to Paisley Caves, the term ‘Clovis’ is generally designates a time period as opposed to the presence of distinctly Clovis technology (Prasciunas 2011: 108; Aikens et al. 2011: 28), which spanned a very short 200 to 400 year period between approximately 13,110-12,660 cal BP primarily east of the Rocky Mountains (Meltzer 2010: 254–255; Waters and Stafford 2007: 1123–1124; Beck and Jones 2010: 82). Western Stemmed Tradition projectile points were prominent in the Northern Great Basin and adjacent regions and were a long- lived technology that spanned more than 6,500 years (Jenkins et al. 2012; Davis and Schweger 2004; Green et al. 1998: 449; Willig and Aikens 1988). Not confined to any single type of environmental condition, the highly adaptive and distinct WST tool- kit spanned from the oldest levels of Paisley Caves through to approximately 8,500 years cal BP and over that time, did not change significantly morphologically (Jenkins et al. 2012; Willig and Aikens 1988). The tool kits included stemmed, foliate or lanceolate projectile points, biface scrapers, flake knives, retouched flakes, and unmodified utilitarian flakes

(Jenkins et al. 2013b: 20). Cores used in the production of flakes were likely obtained from storm- beaches near the Paisley Caves or brought from Tucker Hill twenty kilometers to the south (Figure 1.2). Lithic debitage and cordage recovered from Cave 2 Younger Dryas deposits were found in stratigraphic association with environmental indicators such as seeds and cones, suggesting anthropogenic activity to account for the presence of economically important plants in the assemblage (Dexter and Saban 2014; Jenkins et al. 2013b). Also recovered were numerous bones of small and large mammals, insects, fish and birds, and large mats of processed pronghorn fur.

While human populations of the Northern Great Basin were likely low during the Late Pleistocene, the deposition of materials indicates that occasionally large groups of 30- 40 or more people simultaneously occupied Paisley Caves while they foraged, hunted and socialized (Jenkins et al. 2013b: 19). Chemical analysis of obsidian recovered from late Pleistocene deposits indicate that these people frequently came from the Fort Rock and Alkali basins to the north to hunt antelope and rabbits (Figure 1.1) (Jenkins et al. 2013b: 10). Previous to Younger Dryas deposits within Paisley Cave 2, the artifact deposits are very sparse. Following the Younger Dryas, a long period of time passed before much activity was seen in the caves again. Overall, human occupations of the Paisley Caves were typically brief and resulted in the deposition of only a few scatters of bones, tools and coprolites (Aikens et al. 2011: 53).

Research into the prehistory of Paisley Caves began in 1938 under University of Oregon archaeologist Luther Cressman (Cressman et al. 1940; Jenkins et al. 2004: 5). Cressman described the stratigraphy of Cave 2 as being intact (1940: 6) and associated artifacts excavated from below Mount Mazama tephra to extinct megafauna forms in the cave’s lower deposits. At the time, Cressman was unsure of the ages of the artifacts and provided a conservative estimate of being “no younger than 4,000 years and no older than 10,000” (1940: 14), placing humans at the Paisley Caves by at least the early Holocene. Cressman’s claims of early human occupation of Paisley Caves was challenged by his contemporaries primarily on the basis that Cressman lacked adequate documentation demonstrating actual associations between artifacts and the remains of extinct animals (Krieger 1944: 355; Heizer and Baumhoff 1970: 5; D’Azevedo et al. 1986: 115; Aikens et al. 2011: 50). Between 2002 and 2011, Dennis Jenkins revisited Cressman’s previous work and by using different excavation and recording methods, modern dating methods and DNA analysis were able to demonstrate that humans had occupied the site by at least 14,300 years ago (Gilbert et al. 2008; Aikens et al. 2011: 50; Jenkins et al. 2012a).

Cultural materials recovered from Cave 2 includes obsidian Western Stemmed Tradition point fragments, cordage, basketry fragments, manos and metates, scrapers, coprolites (human and animal), butchered or modified bones and fur, and megafauna bones. In addition to artifacts, a host of organic remains ranging from seeds, conifer cones, herbaceous plant remains, and hundreds of small mammal, fish, bird and reptile bones. Distributional analysis of artifacts, coprolites and megafauna bones across Cave 2 strata resulted in identification of a relationship between megafauna bones and artifacts (McDonough et al. 2012: 5–11; Jenkins et al. 2013b: 17). The with the exception of a very delicate bone needle recovered from the Younger Dryas deposits in Cave 2, the artifact assemblage does not change in use or engineering approach between the Younger Dryas and the early Holocene. The primary thing that is different is the number of artifacts deposited in Younger Dryas deposits compared to deposition during the early Holocene. Due to the sheer number of artifacts coupled with related organic materials, including large mats of antelope hair and processed bone, it may be safe to conclude that a greater number of people were present in Cave 2 during the Younger Dryas using the cave as a processing center, though for what extent of time remains unknown. Further, with the presence of awls, basketry and so forth, it is also safe to conclude that there were multiple activities occurring inside Cave 2, which is likely due to a large group of people, although it is unclear whether this were repeated occupations or a single intense occupation that resulted in the high artifact deposits of the Younger Dryas.

Botanical Lens

In Cave 2 at approximately 1365.80 to 1365.62 MASL there is a dense botanical deposit colloquially called the Botanical Lens (Jenkins et al. 2013b: 4; Jenkins 2013c: 496). The Botanical Lens is dated directly to the Younger Dryas period and bracketed below by a silt lens dated immediately prior to the Younger Dryas and in some places, is capped by a thin silt deposit dated to approximately 11,500 cal BP (Jenkins et al. 2013b: 7–12). The Botanical Lens is composed primarily of a sagebrush matting of branches, twigs, bark and other organic particulates, including disaggregated coprolites, crystalized urine, bones, feathers, claws, rat and bat feces, different kinds of hair and mummified scraps of animal hide (Figure 2.9 and 2.10) (Jenkins et al. 2013b: 9).Also included in the Botanical Lens were smashed and split bones, including pronghorn, deer and mountain sheep, as were abundant pronghorn hairs cut from pronghorn underbelly (Figure 2.10) (Jenkins et al. 2013b: 9). Associated cultural materials also include a needle, a bone awl, a concentration of lithic debitage, pieces of braided sagebrush rope, twisted sagebrush cordage, knotted strands of sagebrush bark, a wooden peg, sinew wrapped twigs, pumice abraders, scrapers, utilized flakes, retouched flake knives, and a Western Stemmed Tradition projectile point base (Jenkins et al. 2013b: 12). The pronghorn hair was dated to 12,070- 12,390 cal BP and a lock of shaved human hair with attached lice egg sacks dated to 12,460- 12,680 cal BP (Jenkins et al. 2013b: 9), establishing a Younger Dryas age for the Botanical Lens.

Macrobotanical remains recovered from the Botanical Lens (Dexter and Saban 2014: 3) included Poaceae, particularly Indian ricegrass (*Oryzopsis hymenoides* also named *Achnatherum hymenoides*. Indian ricegrass is known to be cached by rodents (Longland and Ostoja 2013: 1–2), however the relatively low amount of grass pollen compared to high seed counts contained in the Botanical Lens indicates that grass was not growing in large quantities close to Cave 2, reducing the chance of rodent caching. Other botanicals include members of Brassicaceae, including cress (*Rorippa* sp.), chenopods (*Chenopodium* sp.), various members of Asteraceae, stinging nettle (*Utrica dioica*), bulrush (*Scirpus* sp.), rush (*Juncus* sp.) and juniper (*Juniperus occidentalis*). Juniper macrobotanical remains includes male and female cones and tree boughs as well as seeds. There is an absence of juniper pollen until the Holocene. As pollen is indicative of the local environmental structure the presence of juniper macrobotanicals indicates that the juniper remains were likely transported and deposited in Cave 2 by human activity. Rodents do not transport macrobotanicals from beyond a one to two hundred foot range (Grayson 1993: 118). With the presence of male cones, if there had been juniper present within a fifty to one hundred foot range and the macrobotanicals were blown into the cave then there would have been pollen present as well.

Chapter 3: Methods

Sediment Sampling

The western portion of Paisley Cave 2 was opened on July 27, 2012 for the purpose of sampling sediments for this project and was supervised by Dennis Jenkins. The profile of 2/6B was exposed after the removal of boulders and sandbags placed there from previous excavations to protect the site. Once access to the profile wall was clear, visual inspection determined the best location to collect bulk sediment samples (Figure 1.3). Selection of the profile was based on the lack of bioturbation or other signs of significant disturbances to the stratigraphy. Vertical measurements were made using a metal spike established at the top of the 2/6B profile at an elevation of1367.70 MASL. Once location and elevation were established and photographed a 20 cm wide sampling area was outlined in twine down to the lowest reachable level. The top of the sampling area was then measured to the base of the Mazama tephra layer, giving an elevation of 1366.55 MASL.

Beginning at the base of the Mazama tephra, 3 cm high by 20 cm wide sediment sample blocks were removed at 5 cm depth intervals with 2 cm buffer between samples to avoid contamination. Sediments were collected into previously labeled polypropylene bags using a trowel that was cleaned between levels. Including the surface sample 22 samples averaging 100 cubic centimeters (cc) volume of sediments were taken at each level. Sediments containing modern day pollen was collected on the debris slope immediately above Cave 2/6B as close to the boulder capping that unit as possible (Figure 2.5). Approximately two centimeters of surface sediment was brushed away to reveal relatively undisturbed sediments for sampling.

Geochronology was established by using associated ^{14}C dates obtained from units sharing related elevations within Cave 2. Figure 2.5 shows the units in yellow. The known dates and the stratigraphic elevations they were obtained from are shown in bold on Table 1. Age ranges between the ^{14}C dates were averaged between two known dates then averaged again until all stratigraphic levels were assigned an age range. These ages are shown italicized on Table 1. Two ^{14}C were obtained directly from the unit 2/6B sediment profile. These were from levels 8 and 9 and were calibrated to 9,094 and 9,700 years before present, respectively.

Pollen Extraction Process

Chemical pollen extraction procedures followed Smith (1998), Pearsall (2001: 262) and Bryant and Holloway (1983: 199). The extraction procedure began by washing sediments to remove as many impurities as possible. In the case of the highly organic and polygenetic sediments of Paisley, these impurities included amorphous plant materials, urine crystals and feces. Sediments were sifted through screens to reduce the amount of gravel and larger portions of animal feces, 20 cc of which were placed into 50 cc plastic centrifuge tubes. After measuring our 20 ccs of sediment, each sample was then dumped into individually numbered 1,000 mL Nalgene beakers to begin the washing process.

Two *Lycopodium* tablets was added to each centrifuge tube, providing exotic spores needed to measure pollen concentrations, with the addition of a small amount of 10% hydrochloric acid (HCL) to dissolve the tablets. Once the tablets were sufficiently dissolved 30 g of sodium hexametaphosphate $(NaPO_3)_6$ was dissolved in 270 mL of warm distilled water to produce a 10% solution, which was then divided into the eight beakers. Sodium hexametaphosphate helps break up sediment aggregates and disperse pollen grains. This was followed by filling the beakers with room- temperature distilled water up to the 1,000 mL level, stirring and letting them sit for eight hours to let materials settle. After eight hours the water with suspended material was poured off, leaving the heavier sediments remaining on the beaker bottoms. The process was then repeated twice a day for seven days. Once the water was clear after sitting eight hours, the sediments were transferred back to 50 mL test tubes.

The chemical pollen extraction process was performed inside a fume hood. To begin the chemical process, 20 ccs of 10% HCL was added to the tubes in order to remove as much water from the sediments as possible as water reacts violently to hydrofluoric acid (HFL). Sediments were then centrifuged to remove remaining HCL. The hydrofluoric acid treatment removes silicates from the sediments. The HFL is also used to wash sediments from their 50 mL test tubes into labeled 200 mL Nalgene bottles. The bottles are used to contain any violent reactions between HFL and any remaining water the HCL wash did not remove from the sediments. Sediments were capped and left to sit inside of the fume hood for 24 hours. After the HFL treatment was complete, sediments were transferred back into their 50 mL tubes. HFL was removed using HCL, after which double distilled water was used to remove any remaining HCL.

Pollen grains were separated from remaining sediments by means of suspension using a heavy liquid of zinc bromide ($ZnBr_2$). A 1.9 specific gravity liquid is needed to suspend pollen grains from heavier sediments. To achieve this, a mix was calculated of 48 mL of granular $ZnBr_2$ added to 106.56 mL of double distilled water (DDW). This chemical ratio is specifically for eight centrifuge tubes. The $ZnBr_2$ solution was added to each tube and centrifuged. Centrifuging suspended the pollen grains from the sediments in the upper liquid portion, which was decanted into new labeled 50 mL centrifuge tubes. The $ZnBr_2$ suspension process was repeated twice per sample. Remaining sediments in their original centrifuge tubes were filled with DDW, capped and put into storage boxes for future pollen removal. The new centrifuge tubes with the pollen were filled with DDW and centrifuged in order to remove the $ZnBr_2$. Pollen was then transferred into labeled 15 mL centrifuge tubes.

Glacial acetic acid (GAA) was used to remove water, followed by acetolysis to remove remaining organics from the pollen. Acetolysis is a two chemical process beginning with 4 ccs of acetic acid ($C_2H_4O_2$) then the addition of 0.5 ccs of sulfuric acid per centrifuge tube. The centrifuge tubes were placed into a heating plate for three minutes to increase the chemical reaction. The chemical process was halted using GAA and centrifuged. The remaining pollen was then washed with DDW to remove any remaining chemicals. One drop of safranin stain was added to each tube of pollen grains and allowed to sit for two minutes. Staining was halted by the addition of 4 ml of ethyl alcohol (ETOH). 4 ml of tert- butyl alcohol (TBA) was added to remove as much water and remaining safranin as possible. TBA was then used to transfer the pollen to labeled two dram glass vials. To each vial, silicone oil was added and stirred well and centrifuged to remove TBA and completing the chemical process. Beginning with 20 cc of sediments, approximately 0.05 cc of pollen was recovered per vial. Pollen returns were productive and yielded higher amounts of pollen than had been anticipated due to their location within Cave 2 being relatively undisturbed and protected from deflation and weathering.

Identification and counting pollen grains took place over several weeks in the fall of 2012. Training in identification of pollen grains was provided by Dan Gavin and Erin Herring of the Paleoecology Laboratory at the University of Oregon. A Leica stereo training microscope set at 40x magnification was used to count and identify pollen grains. Pollen counts per genera were recorded on a Bal Supply Cell Counter and *Lycopodium* spores were counted separately on a hand tally counter. Pollen grains were counted to 300 grains total. The results were reviewed by and discussed with Erin Herring to ensure consistency of identifications as well as correct application of statistical measures, both reflecting established paleoecological methodology.

The 300 pollen grain count resulted in a clear and quantifiable pollen signature. Pollen count percentages were measured against introduced exotic *Lycopodium* spore percentages to measure pollen grain density. The spores were obtained from the Department of Geology at Lund University, Sweden. Every batch of spores is unique and the standard deviation is calculated and given per batch. The batch number used in this project was 1031. Tablets contain a mean number of 20,848 spores. Two tablets equal 41,697 spores with a standard deviation of 3,457. Pollen concentrations relative to exotic spores can be seen in the appendix section of this report.

The quantification of pollen counts followed an established approach used by paleoecologists and described by Grimm (1987) and Smith (1998). These counts were entered into and statistically separated into distinct groupings using the algorithmic program Tilia 1.7.16. Tilia performs two primary analytical functions. First, the software measures pollen percentage distributions by stratigraphic levels, and then maps the results onto a diagram showing temporal shifts over time. The second function statistically differentiates pollen zones. There are different types of zonal categorical ordering (Hedberg 1976) but the most common used in palynology is the `assemblage zone'. Here the zones are defined as bodies of sediments that are characterized by distinctive natural assemblages of pollen and spores (Bennett 1996: 155).

Pollen counts were first organized on an Excel spreadsheet, converted from absolute grain counts to percentages and then imported to Tilia. Tilia searches the dataset for most similar and stratigraphically adjacent sample groupings and begins to divide them. Identification of distinct pollen zones is a two part approach: agglomeration and splitting (Bennet 1996: 156). Tilia first agglomerates, or clusters, related groups then splits the clusters according to differences. The groupings were identified through constrained incremental sum of squares, or CONISS. The purpose of the sum of squares cluster analysis is to minimize the total within-cluster dispersion of related groups around a central mean or median (Grimm 1987: 14). The variance within and between stratigraphically constrained clusters of pollen percentages were then measured using CONISS. The result was clustering of overall optimally related groups adjacent to each other and constrained by stratigraphic levels and the groupings shown as a dendrogram. Each combination is then treated as a single sample, after which Tilia repeats the search for smaller and smaller combinations. The diagram results of CONISS for Cave 2/6B is shown on Figures 3.1 and 3.2.

Chapter 4: Pollen Results

Analysis Results

In the initial test portion of this project, pollen was counted and identified up to 100 grains with notes made on anomalous features such as an increase in algae or bryophyte spores other than the *Lycopodium* exotics. The CONISS analysis results (Figure 3.1 and 3.2) shows distinct floristic periods coinciding with the Younger Dryas period at approximately 12,800-11,500 cal BP (Louderback 2007: 25; Mayewski et al. 1993: 195), the Pleistocene- Holocene boundary at ca. 11,000 cal BP years ago, and several other smaller groupings that may represent Winter Lake fluctuations up to the point of the Mazama eruption. Figure 3.2 is a truncated version of the entire pollen diagram reduced to key genera and families.

The possibility that over- representation of high pollen producing and perennially present plants of the Summer Lake sub- basin area including *Pinus*, *Artemesia* and *Chenopodium* might skew any paleoenvironmental interpretations was considered. To test for this, the genera listed were removed from test calculation runs conducted in Tilia. Each truncated test resulted in the same time period distinctions as the non-truncated results. In addition to the clearly defined pollen zone periods, the percentage results reaffirmed the views of many Northern Great Basin researchers that the late Pleistocene to early Holocene vegetation surrounding Paisley Caves was a mosaic of grasslands, forest, lake, marsh, upland desert and steppe environments (Jones and Klar 2010: 11–12, 14; Grayson 2011: 164–168). Paisley Caves pollen does not reflect tundra conditions identified farther east in the Northern Great Basin by Troy Péwé (1983) and Peter Mehringer (1986: 45) in southeast Oregon.

General environmental conditions, plant taxa and plant distribution data used in interpreting the pollen results of this study were obtained primarily from comprehensive lists of plant communities that have been detected in the archaeological record in areas adjacent to the

Summer Lake sub- basin today (Friedel 1994: 531–598). Also used were plant identification keys for plant habitat and distribution information (Hitchcock and Cronquist 1976), lists of current plant communities from nearby geographic regions (Crowe and Clausnitzer 1997; Franklin and Dyrness 1988; Mason 1980), a comprehensive list of plants found in the Klamath Basin compiled by the Native Plant Society of Oregon (2007), and the online Oregon Flora Project of Oregon State University (Cook et al. 2013). Some of the genera are divided into their own categorical descriptions due to the size of the families or their significance to the assemblage.

Pollen Zone Descriptions

Pollen zones are subdivisions made on pollen diagrams. Tilia defines the subdivisions statistically by clustering optimally related groups adjacent to each other and constrained by stratigraphic levels and then shown as a dendrogram. Separation between groups on the pollen dendrogram (Figure 3.2) is where the biggest shifts in biotic conditions are statistically. Pollen zones mark periods of time where vegetation signatures of a region remain relatively static due to periods of climatic stability. Subdivisions within the zones are grouped according to variations within the stratigraphically constrained groups. These smaller shifts reflect abrupt vegetation changes during periods of rapid environmental variation.

Pollen Zone 1: Late Pleistocene through Younger Dryas (13,699- 11,200 cal BP)

Pollen Zone 1 is the earliest period in this study and is divided into three sub- zones. It is constrained entirely within the late Pleistocene and includes a short period just before and during the Younger Dryas chronozone. Pollen Sub- Zone 1a is located entirely within LU2 and is a single level at the base of the 2/6B sampling area profile 21 (Table 1, Figure 3.2), which corresponds to the original Paisley Caves archaeological excavation level 56 (1365.52 to 1365.55 MASL) and is the only level in Sub- Zone 1a. Sub- Zone 1a represents the floristic signature of the Summer Lake sub- basin previous to the Younger Dryas.

Sub- Zone 1b marks the onset of the Younger Dryas period and includes levels 18- 20 (Paisley catalog 53 to 55) 1365.60- 1365.70 MASL. Halfway through level 20, LU2 switches to more gravelly LU3 sediments. The final portion of Zone 1, Sub- Zone 1c, extends from levels 15 to 17, 1365.82- 1365.72 MASL. Floristic biodiversity is low during the Zone 1 period, with a marked increase of plant diversity observed during the Younger Dryas. Seventeen total taxa were identified in Zone 1 (Table 2).

Examination of Zone 1 as a whole resulted in pollen percentages that included *Pinus* (20-38%), *Abies* (5- 16%), *Salix* (4- 12%), *Artemesia* (10- 28%), *Ambrosia*-type (9%), Tubuliflorae-type (1- 16%) *Chenopodium*- type (10- 21%), Poaceae (3- 6%) and *Typha* (2- 4%). By contrast, the current day pollen assemblage includes *Pinus* (19%), Cupressaceae (9%), *Populus* (2%), *Artemesia* (31%), *Ambrosia*-type (6%), *Chenopodium*-type (18%), Poaceae (3%) and *Typha* (1%). Tubuliflorae-type plants are members of the Asteraceae family and include daisies, marigolds, dandelions and marigolds, and many others. *Ambrosia*-types are also members of the Asteraceae family, and include ragweeds and bursages.

Comparison of Zone 1 with the modern day pollen assemblage (Figure 3.2) shows that trees were present during the terminal Pleistocene, with *Pinus* growing near to the caves during the Zone 1 period. Present in Zone 1 but not in the modern assemblage is *Abies*, which currently only occurs at elevations over 1,676 MASL in the Freemont forest west of Winter Rim. There is no *Juniperus* observed in the Zone 1 assemblage though it does abruptly appear in early Holocene deposits, indicating that *Juniperus* was likely present in the Summer Lake sub- basin during the Zone 1 period, just not near the Paisley Caves. This is supported by the recovery of macrobotanical *Juniperus* berries and cones from Cave 2/6 Younger Dryas deposits. These macrobotanicals were verified as juniper by botanist Richard Halse of Oregon State University in 2013. As mentioned, rodents do not travel far from their nests to collect plant materials (Grayson 1993: 118; Longland and Ostoja 2013), meaning the deposition of juniper material was likely the result of human activity.

Percentages of *Artemesia* do not vary much between the late Pleistocene and today, indicating their longstanding presence around the Paisley Caves butte. The two Asteraceae family sub-groups most indicative of climatic conditions identified for this study are *Ambrosia*-type (ragweed) and Tubuliflorae- type. The types are distinguished between low pollen spine asters *Ambrosia*, which includes ragweeds, and high spine Tubuliflorae, which include sunflowers and daisies.

The appearance of *Ambrosia* in relatively high amounts at the beginning of Zone 1 but disappears during the Younger Dryas period and is replaced by Tubuliflorae- type asters. *Ambrosias* are general indicators of closed environmental conditions, as well as drier climate conditions versus wetter conditions (Thompson 1996: 149; Dennison- Budak 2010: 40,89,93). This is compared to light- demanding Tubuliflorae- type asters which are considered indicators of more open and wetter environments that can be associated with climate change, shifts in the water table or human activities such as agriculture (Heusser et al. 1995: 34, 36; Thompson 1996: 149, 150; Mudie et al. 2007: 15; Hoogzaad 2009: 18, 26, 43). Zone 1 saw a sharp decline in *Ambrosia* and a sharp increase in Tubuliflorae- type, marking a rise in moisture that began just previous to the onset of the Younger Dryas. This view is further supported by a sharp increase in herbaceous plants over conifer trees by the end of the Zone 1 period (Figure 3.2).

The increase in herbaceous plants coupled with a reduction of conifers in Zone 1 was most likely due to resurgence in the water table caused by an increase in precipitation during the Younger Dryas period (Figure 2.2) (Carlson 2013: 127, 128; Bryson 2007; Vacco et al. 2005; Mitchell 1976). Rapid floristic change due to a changing water table was directly observed in an analogous modern setting at Sycan Marsh (Figure 4.1) 48 kilometers west of Paisley Caves (Figure 1.1). The intentional draining of the marsh in the 1950s to increase grazing land for cattle of the ZX ranch resulted in the conifer tree boundary to extend into the once wet marsh area very quickly. Restoration efforts in the 1990s once again allowed water to flood the marsh, resulting in the conifer boundary retreating out of the marsh and replaced by herbaceous plants (Cain 1998).

An increase in the Winter Lake water table is further supported by the higher amount of *Typha* in Zone 1 than what is seen in the modern assemblage. This indicates there was a source of *Typha* pollen much closer to the caves than today. Poaceae shows relatively high amounts during the Zone 1 period and increasing in percentage from the pre- Younger Dryas period into the Holocene. Today grass pollen is low in overall distribution, meaning that the grass pollen probably comes from the talus slope immediately in front of Cave 2.

In summary, Zone 1 moves from cool and arid conditions with conifer trees dominating the plant signature, then shifting to cool and wetter conditions during the Younger Dryas. Herbaceous plants increase significantly during the Younger Dryas, indicating more open areas and fewer conifers until the onset of the Holocene at approximately 11,095 cal BP. Conditions in the Summer Lake sub- basin during the Younger Dryas would have resembled Sycan Marsh today (Figure 4.1).

Pollen Zone 2: Early Holocene (11,095- 8,338 cal BP)

Zone 2 marks the approximate onset of the Holocene period 11,200 cal BP (9600 ^{14}C). LU3 is the sediment type for the entirety of Zone 2. LU3 sediments are defined as firm to hard sediments of polygenetic origins, are heavy in macrobotanical content, amorphous organics and trace gravels as well as substantial amounts of *Neotoma* and *Chiroptera* feces (Jenkins et al. 2012: 225). Zone 2 is subdivided into three sub- zones and shows the largest range of plant taxa of all the zones, prehistoric or modern with thirty-one total genera identified (Table 2).

Pollen percentages from Zone 2 include *Pinus* 22- 37%, *Abies* (9- 25%), *Salix* (2- 14%), *Artemesia* (5- 16%), *Ambrosia*-type (1- 2%), Tubuliflorae-type (1- 7%), *Chenopodium* (7-25%), Poaceae (1- 8%) and *Typha* (1- 3%). Climatically significant and not present in the Zone 1 pollen assemblage is *Juniperus* (1- 3%), *Picea* (1- 3%), *Larix* (2- 4%), *Populus* (1%), Rhamnaceae (*Ceanothus*) (<1%), *Shepherdia* (1%), Sparaginaceae (1- 2%) and Cactaceae (1%).

Conifers presence increases during the early Holocene. Pines remain relatively the same as seen in Zone 1, but *Abies* increase significantly. This increase is especially apparent in the later portions of Zone 2. *Salix* is significantly reduced as compared to Zone 1 but remains present throughout the Zone 2 assemblage. Small but measurable resurgences of *Salix* pollen likely indicate pulses in water table levels. Open environment Tubuliflorae- type asters all but disappear in the final portion of the Zone 2 period and are replaced by the return of more closed-environment indicative *Ambrosia* asters. *Chenopodium* levels do not change significantly between Zones1 and 2. Grasses increase in the latter part of the Zone 2 period. Significant taxa present in Zone 2 includes *Picea* (1- 3%), *Larix* (2- 4%), Cupressaceae (1- 3%), Rhamnaceae (1%), and Cactaceae (1%). In addition to *Typha,* marsh-indicative *Sparganium* (bur- reed) is identified in the latter part of Zone 2 (<1%). The presence of conifers means greater conifer cover near the Caves and a marsh area still present but further away than what had been observed during Zone 1.

Pollen Zone 3: Early Holocene to Eruption of Mount Mazama (7,989- 7,600 cal BP)

The Zone 3 period was floristically diverse, as determined by twenty- four genera identified in the pollen assemblage (Table 2). Pollen percentages from Zone 3 include *Pinus* (35-47%), *Abies* (11- 24%), *Salix* (2- 4%), *Populus* (1- 2%), *Artemesia* (7- 16%), *Ambrosia*- type (1-4%), *Chenopodium*- type (6-12%), Poaceae (6- 9%) and *Typha* (1%). Climatically significant and present in zones 2 and 3 but not in the Zone 1 pollen assemblage is *Larix* (1- 2%), Populus (1%) and Cactaceae (1%).

Pinus is at a slightly higher percentage than in Zone 2. *Abies* remains at the same percentage as in Zone 2. *Populus* is at relatively the same amount as Zone 2, as is Cactaceae. The greatest change between Zones 2 and 3 is no longer present in Zone 3 despite twenty-four genera and families identified. Absent from the assemblage are *Picea* and Cupressaceae, although it is doubtful they were not present in the Summer Lake sub- basin at all. Tubuliflorae-type asters disappear entirely from the Zone 3 period and *Ambrosia*- type asters reach their highest pollen levels since pre-Younger Dryas, indicating dryer environmental conditions.

Poaceae is at higher levels than at any other point in the pollen assemblage, alternately with *Chenopodium* showing its lowest pollen levels. Also at its lowest pollen levels is *Typha*. The marsh is still present but far from the Paisley Caves. A modern analogous setting resembling Zone 3 conditions would be the eastern boundary of Klamath Marsh, located 83 kilometers west of Paisley Caves (Figure 4.2).

Modern Pollen

Pollen from the modern sample shows 19% *Pinus*, 31% *Artemesia*, 6% *Ambrosia*-type, 18% *Chenopodium*, 3% *Poaceae* and 1% *Typha*. The modern assemblage differs from the pre-Mazama zones primarily due to the presence of *Juniperus* 9%, *Quercus* (oak) 1%, and Fabaceae (*Medicago*) 5%. Thirteen genera were identified in the modern assemblage, representing far less plant diversity than in the pre- Mazama assemblage (Table 2). Interestingly, this is only four fewer genera or species than seen during the Zone 1 period, and parts of the modern assemblage are introduced species. *Medicago* and *Quercus* are introduced genera, and many of the grasses are invasive, particularly *Bromus tectorum* (cheatgrass) but also including *Arrhenatherum elatius* (false oat- grass), *Taenatherum caput- medusa* (medusahead), *Bromus rubens* (red brome) (Chambers 2008). *Pinus* pollen can only be coming from Winter Rim today, and as it is only

19% of the pollen input compared to the much higher amounts seen in Zones 1 through 3, it is safe to conclude that the *Pinus* pollen during the late Pleistocene and early Holocene originated much closer to the Paisley Caves than today.

Pollen Results Summary

The pollen diagram (Figure 3.2) shows the fluctuations of the various taxa over time, with Table 2 showing pollen percentages divided by pollen zones. The target time period of this study spanned a cool, gradually warming period in the late Pleistocene to a sudden change in global climate abruptly resulting in cooler conditions over a period of 1,500 years during the Younger Dryas, and finally shifting into warmer, drier conditions during the early Holocene. The pollen results showed high vegetation production within the Summer Lake sub- basin during the Younger Dryas, which undoubtedly would have been attractive to animals than other areas that experienced harsher tundra conditions east of the Chewaucan Basin (Péwé 1983; Mehringer 1986: 45).

The pollen results showed an ecological transition from a cool, arid environment during the first portion of Zone 1 from approximately 13,699 to 12,896 cal BP, rapidly shifting to a cool and wet period for the remainder of Zone 1. There are sixteen plant taxa represented in the assemblage over the entirety of Zone 1, with the majority of the diversity developing during the wetter later portion of Zone 1. The middle portion of the Younger Dryas period saw a dramatic increase in grasses and forbs that out- competed conifers. Conifers became rapidly dominant at the beginning of the Younger Dryas period at approximately 12,896 cal BP and remained so for approximately a 300 year period. Conifers are then replaced during an equally rapid increase in herbaceous forbs, true aquatics and non- conifer trees at approximately 12,569 cal BP. The abrupt rise in high light dependent Tubuliflorea- type pollen is further indicative of a much higher water table resulting in an open, less treed environment and reflects an increase in wetter climatic conditions as a whole in the Northern Great Basin (Goebel et al. 2011; Grayson 2011a: 128–130; Adams et al. 2008; Bryson 2007; Vacco et al. 2005; Mehringer 1986: 31–50; Mitchell 1976; Antevs et al. 1948: 170).

The warmer and more arid Zone 2 marks the onset of the Holocene and shows an ecological shift resulting from a lower water table, as evident by the return of conifers dominating the pollen signature. The pollen diversity of the early Holocene period increase to 31 taxa identified. By the early Holocene, the Chewaucan River stopped feeding into Winter Lake and flowed instead into ZX Lake to the east (Jenkins et al. 2004: 10) causing Winter Lake to recede very quickly. At this time it should be noted that the CONISS analysis on the pollen diagram shows six smaller clusters (Figure 3.2). These may represent lake levels increasing in response to occasional increased precipitation. Bur- reed (Sparaginaceae) is associated with marsh areas of the Northern Great Basin area, appears in the assemblage at this time and *Ambrosia*- type asters (ragweeds) replaced the Tubuliflorae- type asters, indicating greater tree and shrub coverage.

Zone 3 shows a reduction in pollen diversity with 24 taxa represented. Conifers pollen remains high, and the marsh appears to be either much reduced or simply further away due to the continued desiccation of Winter Lake and a much lower water table. Climate was very warm and arid during this time. The modern assemblage shows thirteen taxa, some of which are introduced species, such as *Medicago* (alfalfa) and *Quercus* (oak). Herbaceous plants dominate the pollen assemblage, with conifers weakly represented.

Further Questions

The presence of Hippuridaceae in level 19 bears exploring. Hippuridaceae, commonly known as mare’s tail, is an obligate water plant that could not grow anywhere in close proximity to the caves. The question is how did pollen from a small water plant get into cave deposits in enough quantity to be statistically measured? While mare’s tail is anemophilous (wind pollinated) (Dennis and Halse 2008: 171) the flowers are very small, inconspicuous and do not produce a great deal of pollen. At approximately 12,800 cal BP the Winter Lake shoreline was 1.5 to 2 linear kilometers west of the caves, as was the prehistoric course of the Chewaucan River draining into Winter Lake (Jenkins 2013c: 491–492; Grayson 2011b: 117; Negrini et al. 2001: SP1, SP3). Is the presence of this unlikely pollen due to human or animals bringing plants into the cave, or did wind and water blow some blooming plants into Cave 2? Alaskan natives as well as Eskimo and Inuktitut people use mare’s tail in soups and as relishes, as well as medicinally to treat wounds (Moerman 2010: 127–128).

Chapter 5: Human Occupations of Paisley Caves

Relationship of Younger Dryas Environment and Cultural Materials

During the Younger Dryas period, the pollen record from Cave 2 showed an increase in mesic plants. The precipitation increase of the Summer Lake sub- basin was measured using mesic plants as proxy indicators of higher water levels as their presence can only be due to increased water present in the area. A mesic ecology is defined as a type of habitat with a moderate or well- balanced supply of moisture. For the purpose of this paper, 'mesic plants' include true hydrophytes as well as non- conifer trees and certain herbaceous plants that increased in numbers due to a higher water table. Plants selected as moisture proxies are shown in Table 3. Mesic plants are a combination of aquatic plants coupled with herbaceous plants representative of mesic environments. These were identified and quantified via their percentages per Pollen Zone as seen on Table 2.

Proxy evidence of human activity is represented by cultural material counts, which could be representative of either a single, intensive creation period over an undetermined amount of time, or were deposited over multiple occupations of the Paisley Caves. Cultural activity frequencies were measured using only formed tools that included projectile point bases, scrapers, modified wooden artifacts and cordage. Other materials, including seeds, animal bones lacking evidence of modification by humans were not included in the counts. Also not included was lithic debitage, as a single projectile point reduction event could result in many flake pieces that could skew the artifacts counts. Resulting artifact totals for Cave 2 per level are also shown on Table 3. Site use intensity based on artifact remains can be problematic, especially for a small cave such as Cave 2 (Hietala 1984: 79), however, as Dennis Jenkins stated that he feels the density of artifacts in the Botanical Lens represents a high number of people at the Paisley Caves, then within that thinking I felt it logical to use artifacts that were of the same or similar type as proxies for site intensity use. However, I am not stating that more artifacts meant more people present at any given time, only that the formed tool artifacts can be proxies for intensity of site use.

Working on the assumption that mesic plants can be indicators of high amounts of water present in the lake basin, a simple frequency graph comparing mesic plant percentages to formed tool artifact counts was run in Excel (Figure 5.1). Pollen percentages were used as they, when counted against introduced exotic spores with known standard deviations, result in far better measures of environmental patterns and frequencies than actual pollen grain counts. The formed tool artifacts numbers are actual counts. The results showed a positive relationship between moisture levels and human activity levels in Cave 2 during the Younger Dryas.

Two things are evident on the graph. First, the mesic plants line shows relatively high and low variations (high peaks and valleys), likely reflecting pollen depositional rate variations. Second, there appears to be a close relationship between the rise in mesic plants at the onset of the Younger Dryas period followed by a rapid rise in formed tool artifacts soon after. This small lag could represent humans taking some time to respond to the rise in the water table (meaning greater resources) or it could mean a more rapid increase in human activities in the Summer Lake sub- basin area. The reality is likely somewhere in between.

A chi square Poisson regression was run in JMP v.10 to test the strength of the relationship between mesic pollen and formed tool artifact frequencies using the same totals shown in Table 1.3. A Poisson distribution focuses on the number of discrete events or occurrences of seemingly unrelated variables over a defined interval of time. By sampling 5 cm increments, the 21 levels represent ‘moments’ in time that are independent of what occurred before or after it. The independent variables were the mesic plants, as they increase or decrease within portions of time independent of human activities. The dependent variable was formed tool artifacts, as according to the hypothesis stated at the start of this thesis, their increase is directly reliant on an increase in water levels near the Paisley Caves. Poisson regression allows use of percentages of independent variables for comparing frequencies, so I was able to leave those concentrations intact. The results of the analysis ($r = 67.54$; df = 19; $p < .0001$) shows a strong correlation between increase in formed tool artifacts during the Younger Dryas and the increase in mesic plants in the Summer Lake sub- basin (Figure 5.2).

Additional relationships between the Botanical Lens and environment of the Paisley Caves during the Younger Dryas can be described further. First, the Botanical Lens in Paisley Cave 2 shows direct association related to a higher water table with the presence of a processed antelope kill present throughout the deposit (Jenkins et al. 2013b: 9–13). Antelope would have been relatively rare immediately to the west of the Paisley Caves during a tree dominant period, as being fast escape prey animals antelope prefer open areas with long clear views (Schemnitz 2005). This does not mean there were never antelope near the Caves during highly treed periods, but that pollen confirmed indicators of open areas can be directly associated to the presence of processed antelope present in the Botanical Lens deposits. It is estimated that a minimum of two antelope carcasses were processed in the Cave 2 Botanical lens (Dennis Jenkins, personal communication, October 2013), making it probable that the antelope were killed very near to the caves.

Reconstructions of past fluctuations in grasses, herbaceous and arboreal flora allows us to consider what type of fauna the Summer Lake sub- basin might have sustained during the late Pleistocene to early Holocene period. The remains of large animals recovered during excavations at the Paisley Caves include horse, camel, elephant (protein), bear, and recently confirmed, bison (Dennis Jenkins, personal communication, April 2014). Also recovered were artiodactyl and much smaller faunal remains, including reptiles, birds and fish. Pointing out the faunal range relative to this study is not to imply that humans hunted all of those animals, but to demonstrate the ability of the area to support certain types of animals at different times, particularly grazers versus foragers. The presence of willow, alder and other soft- leaved plants would be attractive to browsers such as mastodon, deer or ground sloth. Alternately, a significant increase in grass and open area, light- loving forbs would attract grazers such as horse, elk, antelope and mammoth. An increase in marsh plants would attract higher numbers of water fowl and amphibians.

Finally, after reviewing macrobotanical remains collected during field school excavations in Cave 2 during 2011, juniper stood out as an unusual macrobotanical outlier in the Botanical Lens. The dominant conifer in the Chewaucan Basin today is juniper (*Juniperus* sp.) with pines (*Pinus* sp.) present at elevations over 2,000 MASL. Currently the nearest juniper to the Paisley Caves is 5 miles south and 8-10 miles west. The nearest pine to the Paisley Caves is 10-13 miles west. Both junipers and pines produce enormous amounts of pollen. Pine pollen was recovered from all levels of the pollen core, but no juniper pollen was recovered from late Pleistocene aged sediments (Figure 3.2). Juniper pollen does not appear in the assemblage until the early Holocene. However, juniper seeds and cones were recovered from the Botanical Lens. The question is if there was no pollen but there were macrobotanicals, how did the seeds and cones get into the assemblage?

The possibility that rodents brought juniper remains into Cave 2 was considered. Most juniper species are dioecious (male and female trees are separate). There would need to be a female tree within rodent scavenging range to for rodent transfer of the berries into the Botanical Lens, but this does not seem likely. Rodents do not transport macrobotanicals from beyond a 150 foot range (Longland and Ostoja 2013: 1–2; Grayson 1993: 118) so it is safe to assume if there was juniper present within a 50-100 foot range of Cave 2, then rodents might have been responsible for the berries in the deposits. Alternately there would need to be a male juniper tree within the same range to account for the presence of male cones, or a male tree to deposit pollen although the range for this is much larger.

The presence of juniper macrobotanicals coupled with the absence of juniper pollen from the same Botanical Lens level means that macrobotanical juniper remains were likely deposited in Cave 2 by human activity. Further, as there does not appear to be any juniper in the area of the Paisley Caves at this time, the berries and boughs were probably transported from elsewhere and deposited in Cave 2. Juniper berries were an important food source for Great Basin indigenous people (Moerman 2010: 133–134; D’Azevedo et al. 1986: 58, 399, 475). If it can be determine where the nearest juniper was to the Paisley Caves during the Younger Dryas, a possible foraging area may be established, and with that, the possibility that other new archaeological sites may be found.

Chapter 6: Conclusion

This project compared palynological evidence of environmental change against the artifact assemblage of Paisley Cave 2, and attempted to see if climatic changes of the Younger Dryas chronozone corresponded to changes in cultural activity within the Summer Lake sub-basin. Through sediment sampling it was possible to rebuild the signature of the local vegetation in the Summer Lake sub- basin before, during, and after the Younger Dryas, and plants as identified with pollen were used as proxy indicators to interpret moisture conditions within the Summer Lake sub- basin. The resulting conditions showed an increase in precipitation and a rise in the water table that corresponded strongly to a dense cultural deposit in Cave 2. The higher water table was a result of increased precipitation originating in the Pacific and moving inland (Vacco 2005), cooler temperatures resulting in less plant evapotranspiration (Goebel et al. 2011: 481, 494), increased winter precipitation combined with lower evaporation rates (Figure 2.2) and the Chewaucan River changing its course and draining into Winter Lake (Jenkins 2013c: 491–492; Allison 1982: 16, 19, 38). Formed tool artifacts were used as the cultural proxy measures of human activity fluctuations in Cave 2.The formed tool artifacts strongly mirrored the increase in water levels in the Summer Lake sub- basin, which I am interpreting as an increase of cultural activity during the Younger Dryas in direct response to a higher water table resulting in increased carrying capacity and an increase in marsh resources.

The cultural mechanisms that resulted in a human activity increase during the Younger Dryas within the Summer Lake sub- basin are still unknown. The measurable increase in environmental carrying capacity may have resulted in people staying at the Caves for longer periods of time. Or the increased carrying capacity may have enabled more frequent but shorter stays at the Caves, or perhaps larger groups of people were occasionally staying at the site for shorter periods of time. Only future site intensity use analysis will be able to answer this. The analysis can be in the form of testing coprolites and locks of human hair recovered from the Botanical Lens for genetic variability showing multiple individuals. It should also become possible to determine seasonality of Cave 2 use. Human coprolites can hold the environmental signature of a given place and time. It may be that the pollen signatures recovered from human coprolites do or don't match the assemblage of the Summer Lake sub- basin, which could indicate travel to the site. Further, the macrobotanicals could also indicate seasonality and time usage of site. At this time, University of Oregon's Jaime Dexter- Kennedy is writing her doctoral dissertation on this very subject, the results of which should be available within a year.

The Chewaucan River and the edge of Winter Lake and its marsh were both no more than a kilometer and a half away from the Caves during the Younger Dryas. It was likely economically more sound to utilize the Caves during foraging movements when water sources and resources were very close by, and as the lake receded and the Chewaucan River changed course away from the Summer Lake sub- basin, it was no longer economically feasible to make the long hike up the 5-Mile Butte talus slope just to reach the Paisley Caves when a temporary camp could be established much closer to water and food sources. An analysis of seasonal food items recovered from the Paisley Caves during the Younger Dryas will help clarify any questions of seasonal use. It is probably a combination of the three scenarios listed above that accounts for the intensity of artifact deposition in Paisley Cave 2 during the Younger Dryas.

Wetter conditions resulted in a higher environmental carrying capacity beneficial to both humans and fauna, and fresh water sources being in very close proximity to the Paisley Caves themselves. It is reasonable to postulate that when fresh water was further away from the caves, it became more practical to create temporary shelters closer to it than to spend energy hiking up a steep talus slope to the caves. Whether increased cultural activity was a result of increased human activity showing multiple short occupations with increased artifact manufacture and deposition in Cave 2 or instead, increased periods of time spent in Cave 2 with human activity slowly adding to the archaeological deposits is unclear at this time. What can be said is that the increased carrying capacity of the Summer Lake sub- basin did affect forager behavior in a distinct way. Following the Younger Dryas, never again is the amount of cultural debris as numerous or concentrated as what was recovered from the Botanical Lens.

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Figures

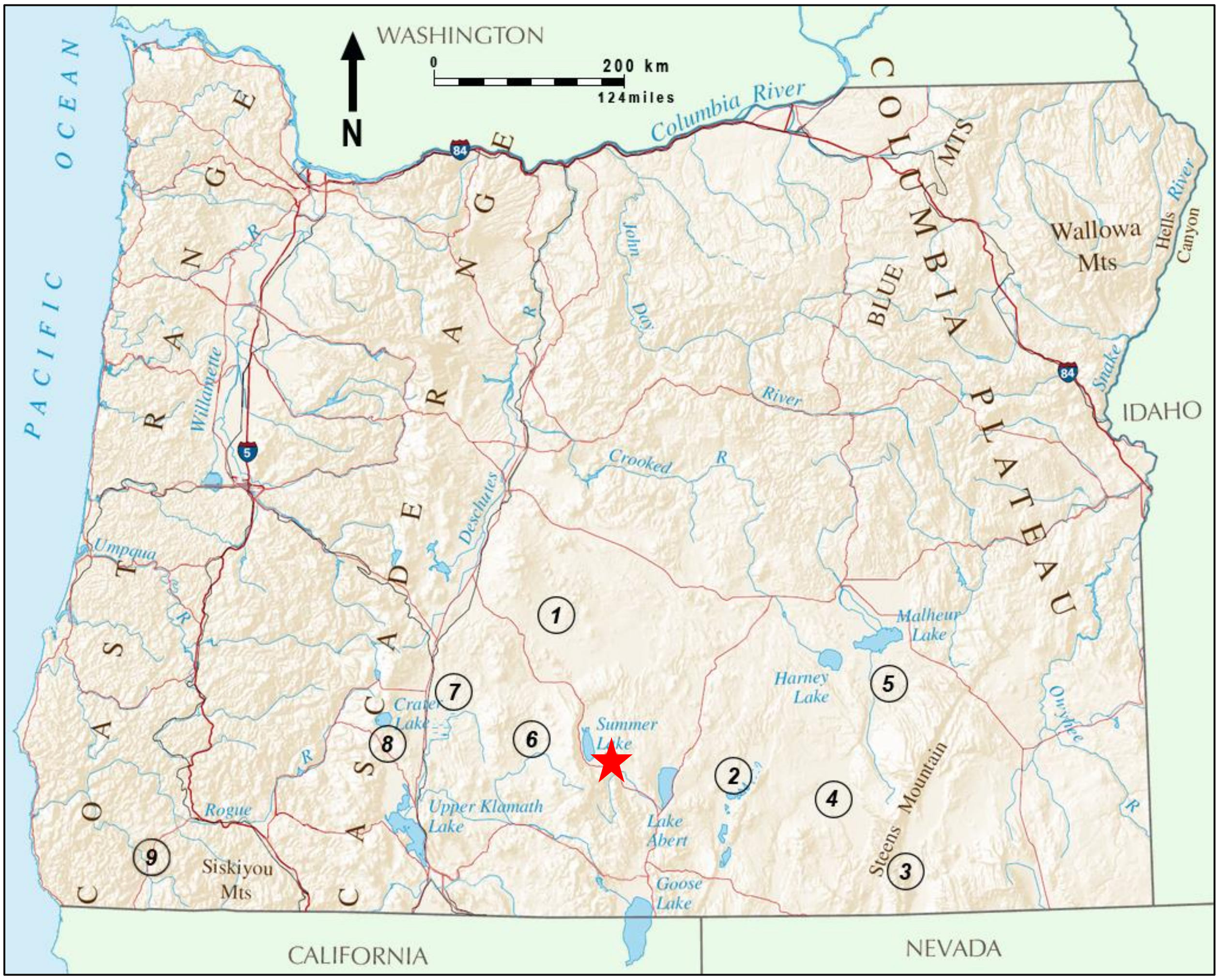

Figure 1.1: Location of Paisley Caves (red star) South Central Oregon. Other locations listed: 1. Fort Rock Basin, 2. Warner Valley, 3. Steens Mountains, 4. Catlow Valley, 5. Diamond Ponds, 6. Sycan Marsh, 7. Klamath Marsh, 8. Mount Mazama (Crater Lake), 9. Oregon Caves.

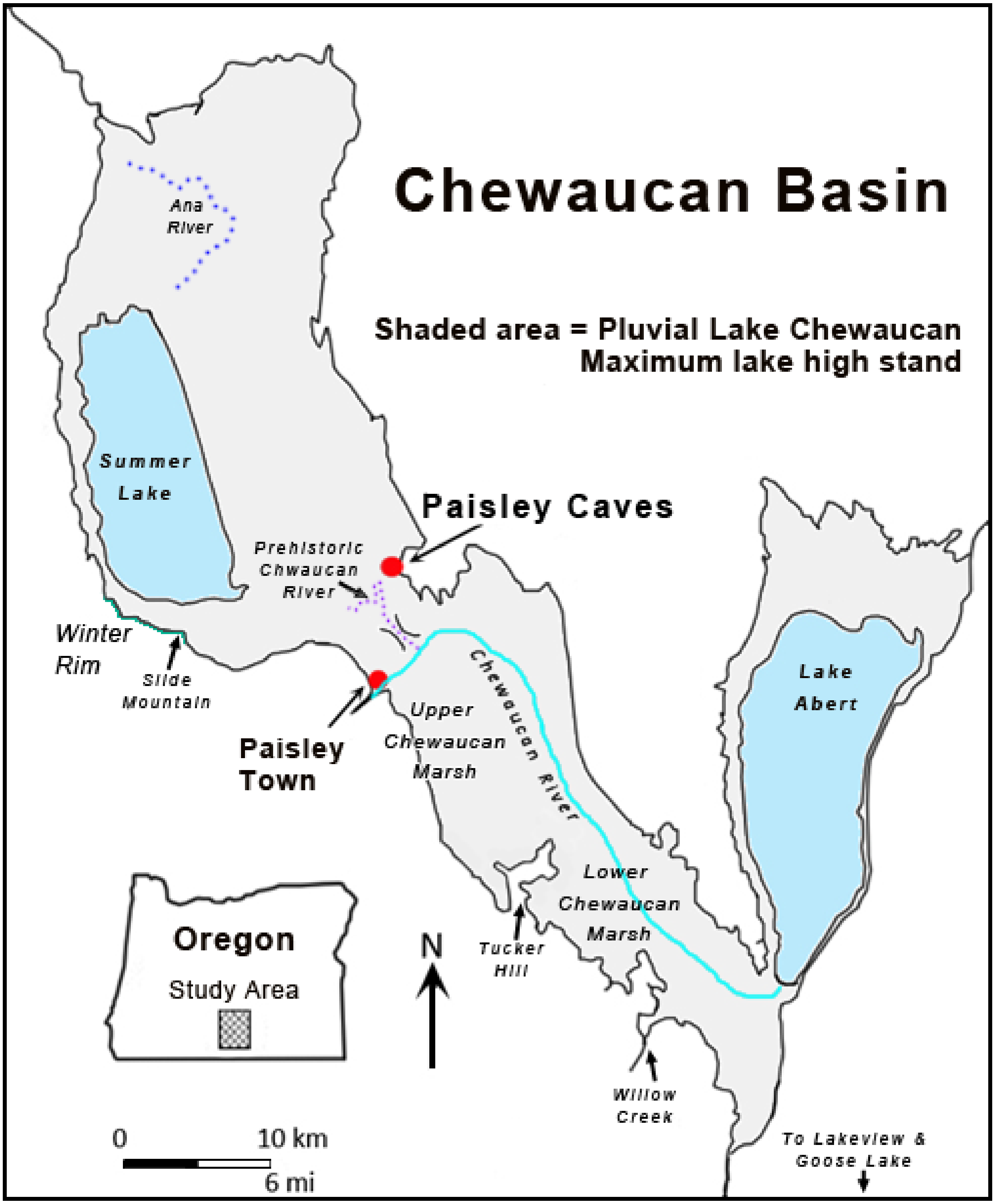

Figure 1.2: Map of the pluvial Lake Chewaucan basin. Original image Licciardi (2001: 546).

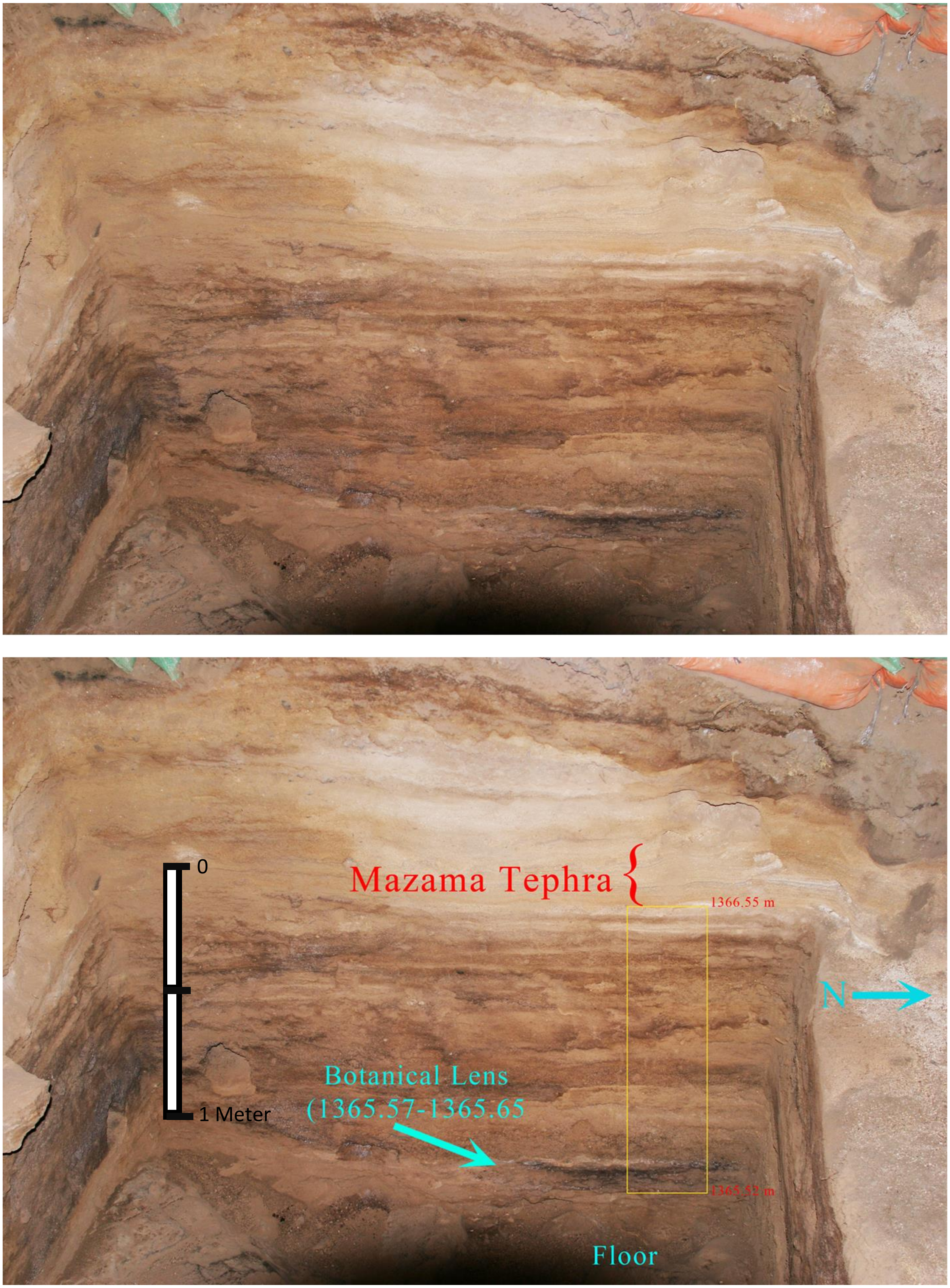

Figure 1.3: Sampling in Cave 2 Unit 6B Paisley Caves, Oregon. Photo courtesy Dennis Jenkins.

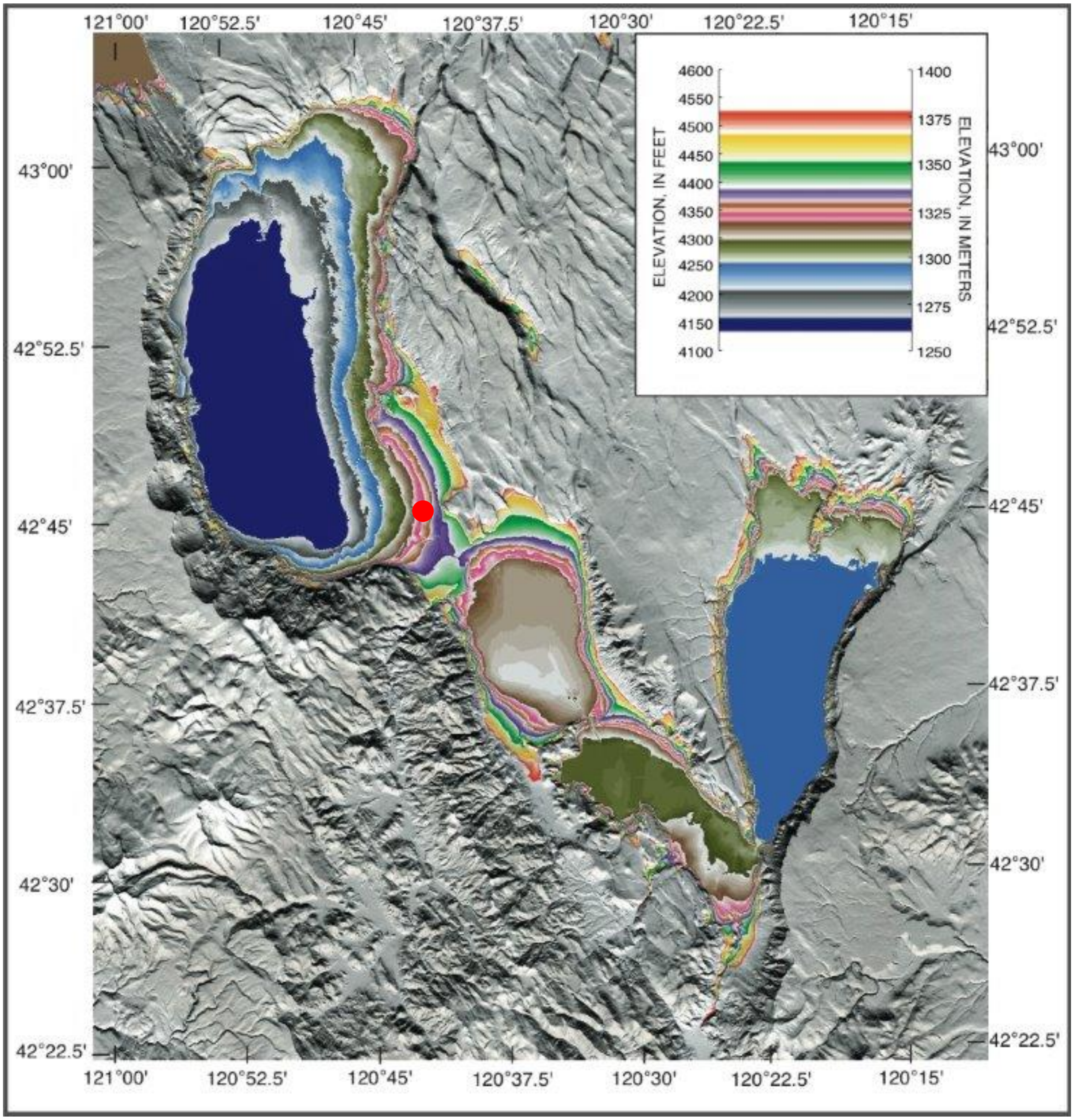

Figure 2.1: Lake level elevations map compiled following Allison (1984) and an unpublished work by Silvio Pezzopane (Negrini 2001: 37). Paisley Caves marked as a red dot on map.

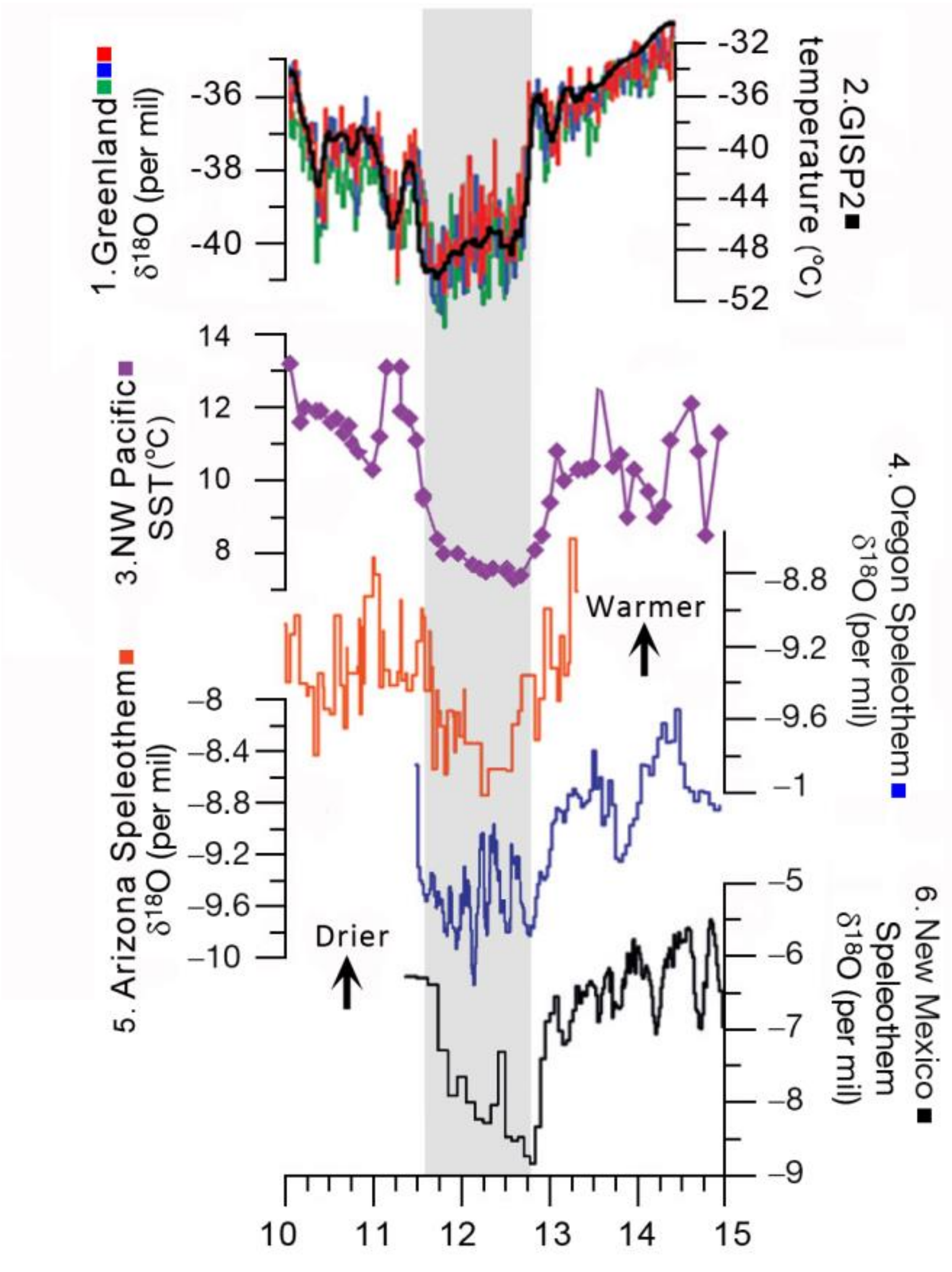

Figure 2.2: Greenland precipitation (Rasmussen et al. 2006) 2. Greenland GISP2 temperatures (Alley 2000) 3. Northwest Pacific sea surface temperatures (SST) (Barron et al. 2003) 4. Oregon Caves speleothem precipitation history (Vacco et al 2005) 5. Arizona speleothem precipitation history (Wagner et al. 2010) 6. New Mexico speleothem precipitation history (Asmerom et al. 2010).

Figure 2.3: View northeast across Summer Lake sub- basin dry lakebed to Paisley Caves. Photo courtesy Dennis Jenkins, 2013.

Figure 2.4: View east of Paisley Caves from Summer Lake sub- basin dry lake floor Cave 2 marked on photo. Photo courtesy Dennis Jenkins, 2012.

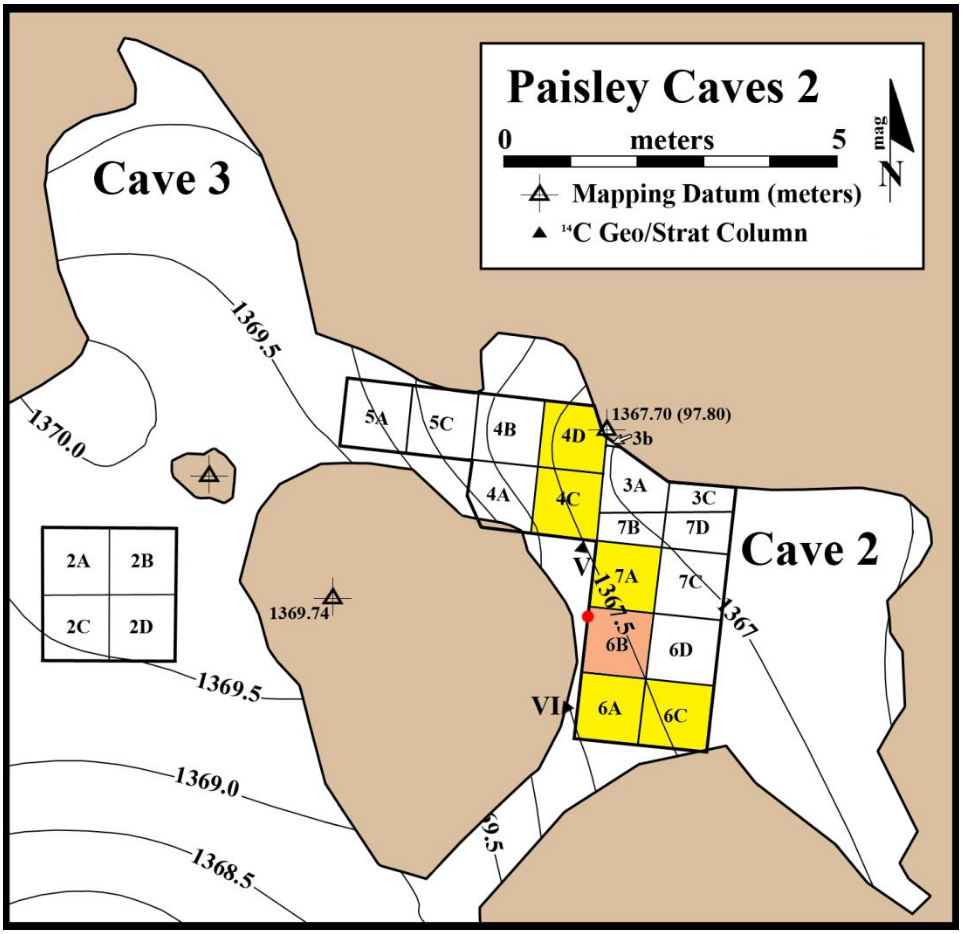

Figure 2.5: Map of Cave 2 layout. Location of project sampling area in red (Jenkins et al. 2013c). Units that provided calibrated ^{14}C ages from related elevations as 6B that were used in analysis. Those ages are seen in bold on Table 1. Two calibrated ^{14}C ages were directly from 6B.

Figure 2.6: Ecological Provinces of Oregon (modified from Anderson et al. 1998: iv). Paisley Caves marked in red.

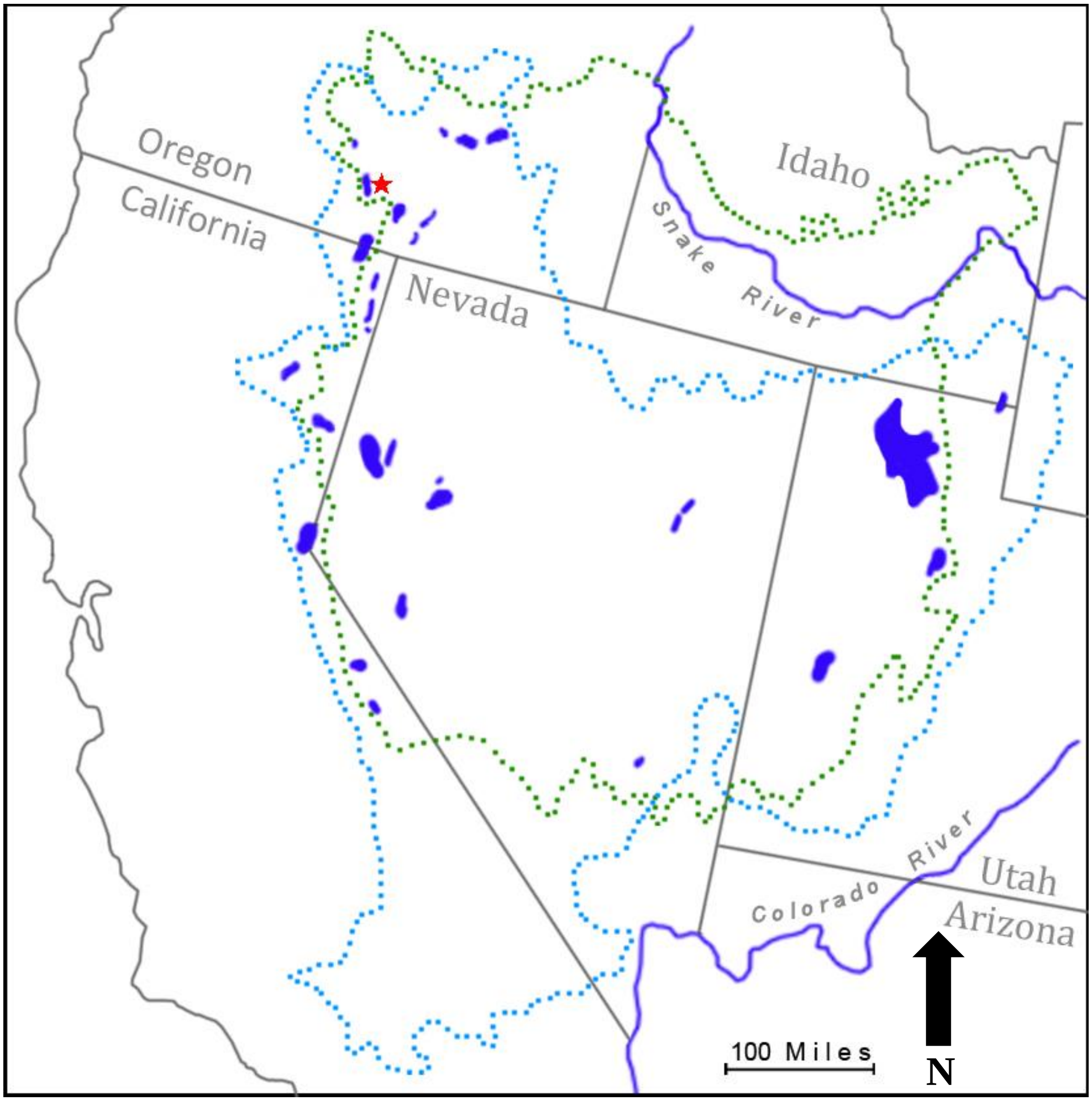

Figure 2.7: Hydrological and floristic Great Basin boundaries map. The blue outlines the hydrological boundary, the green the floristic boundary. Paisley is marked as a red star. After Cronquist et al. (1972) and G.I Smith and Street- Perrott (1983), map modified from Grayson (1993:12,21).

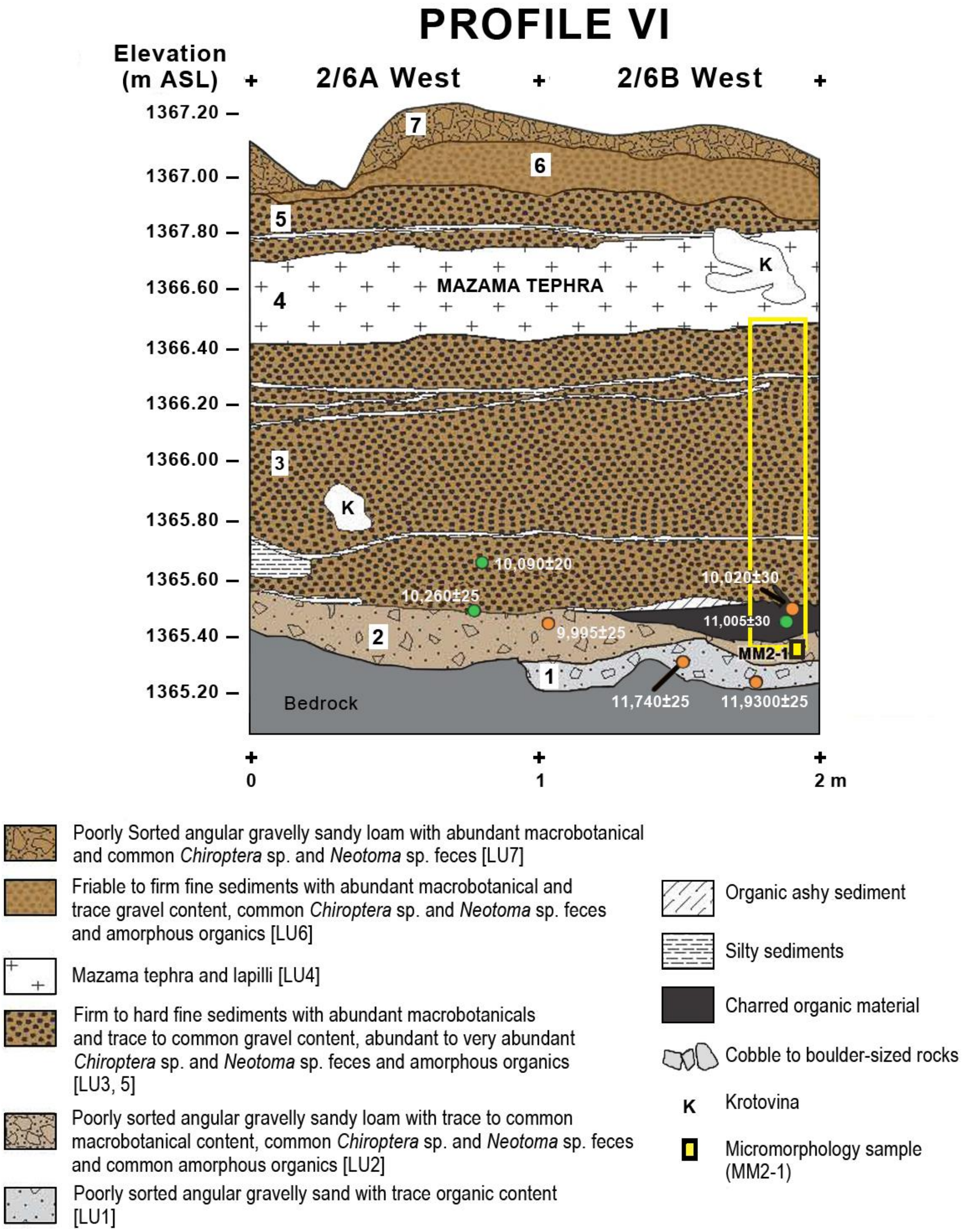

Figure 2.8: Cave 2 Unit 6B sediment wall profile. Yellow rectangle indicates sampling area sampled for this project. Dates on profile shown in radiocarbon years. From Jenkins et al. (2012: 19).

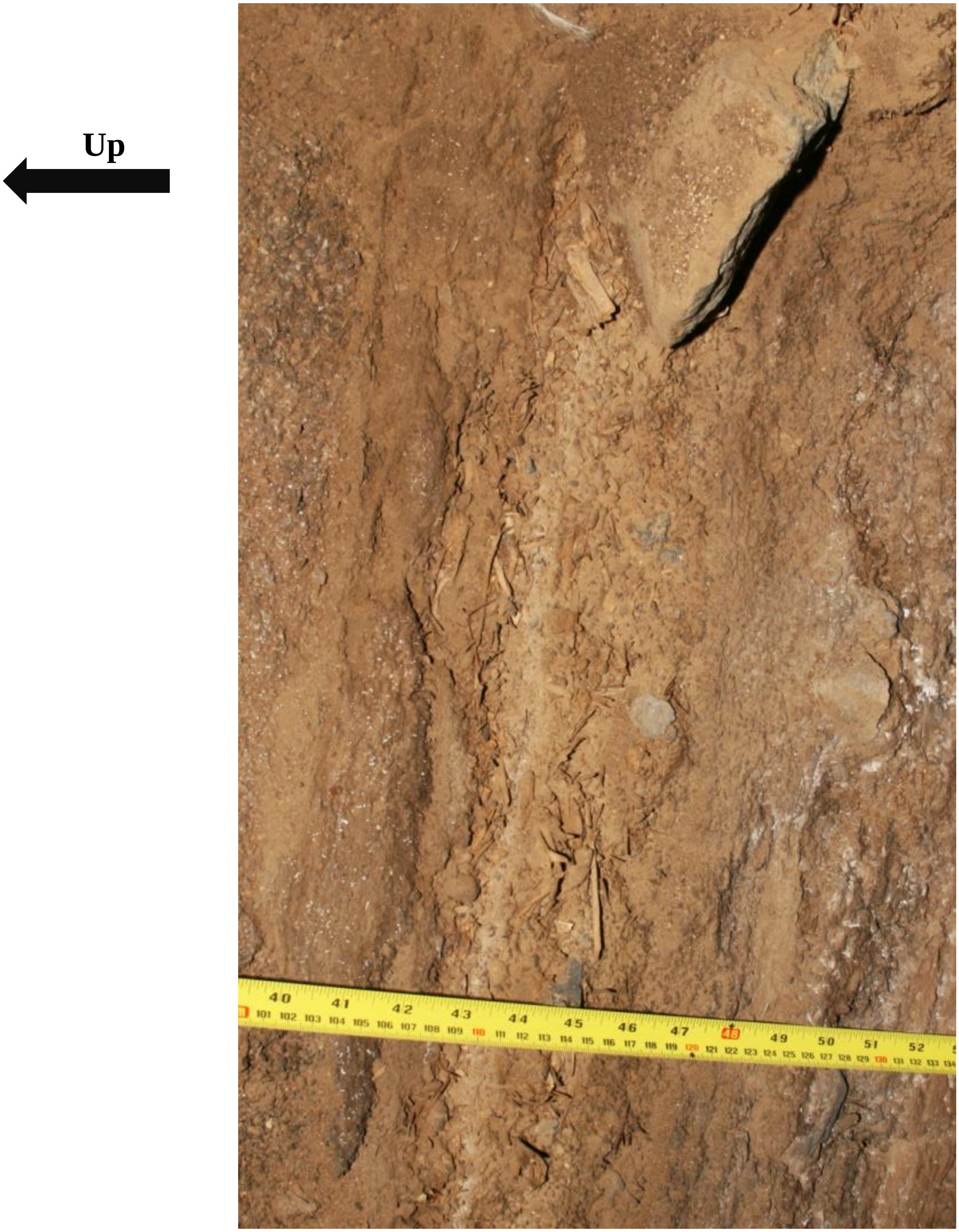

Figure 2.9: Close-up of Botanical Lens Cave 2, unit 6B as it appeared within the stratigraphic profile. Photo is shown sideways, with the bottom of the unit on right side of photo. Photo courtesy Dennis Jenkins, 2010.

Figure 2.10: Excavation of Botanical Lens, University of Oregon field school 2010. Note white antelope fur. Cave 2, Unit 7B. Photo courtesy Dennis Jenkins.

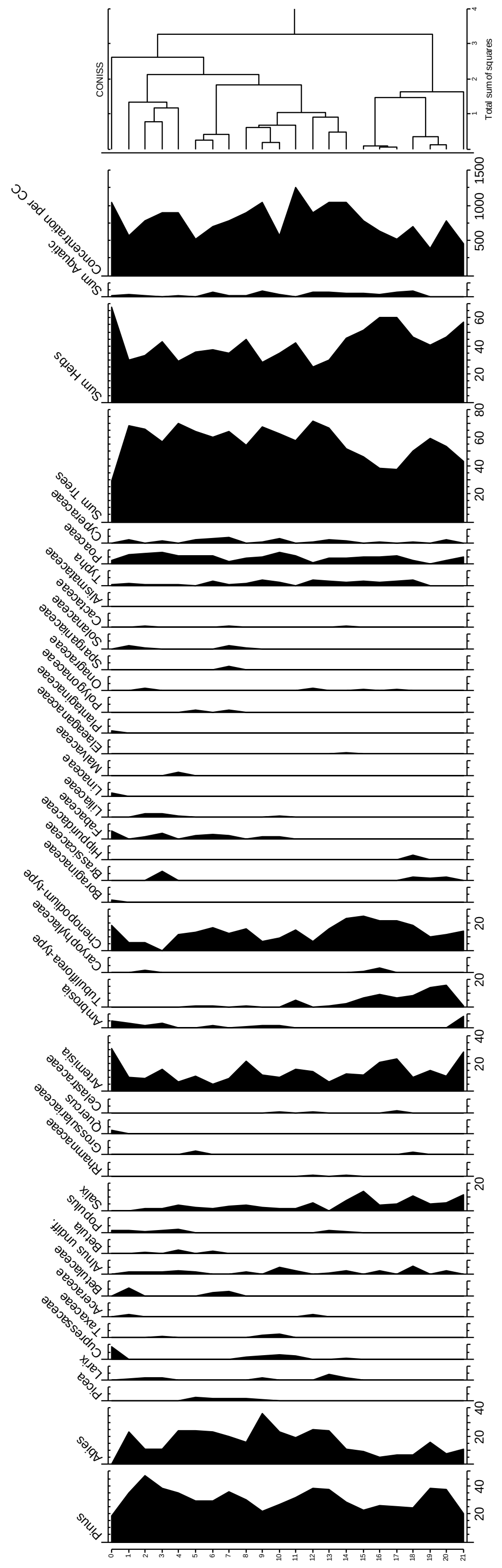

Figure 3.1: Tilia 1.7.16 Paisley 2/6B Pollen output diagram (entire).

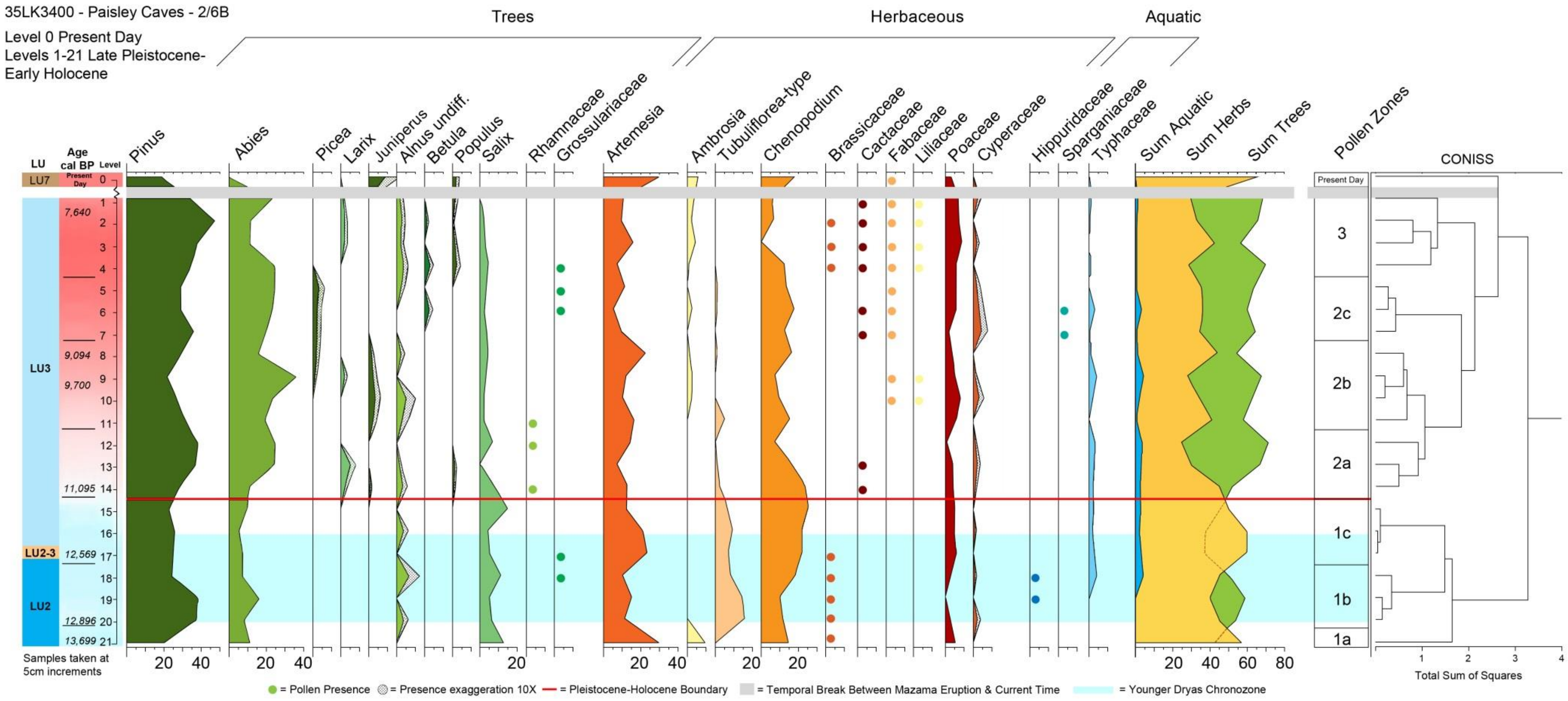

Figure 3.2: Paisley Pollen Diagram 2/6B (truncated to key taxa) Blue bar Younger Dryas. Figure 3.1 is the raw Tilia analysis output including all taxa identified. Figure 3.2 is the truncated version of the diagram with taxa considered unessential to this analysis omitted to improve readability. Chenopodium increases during the Younger Dryas. Conifers rise steeply at the onset of the Younger Dryas period, with herbaceous plants steeply rising towards the middle portion of the Younger Dryas. True aquatic plants also rise during the middle portion of the Younger Dryas, and remain high through Pollen Zone 2. The higher conifer presence seen at the onset of the Holocene represents the recession of the Winter Lake and the water table dropping. All pollen percentages are relative to their overall all percentage counts as constrained to their stratigraphic levels, normalizing their percentage distribution by levels.

Figure 4.1: View of Sycan Marsh facing east. Sycan Marsh represents a similar open ecology to what would have been in present the Summer Lake sub- basin during the Younger Dryas. Image Nature Conservancy 2012 (http: //sub-basin.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/placesweprotect/sycan-marsh.xml).

Figure 4.2: Views of Klamath Marsh facing east. Many conifers combined with a rich aquatic ecology represents the ecology present in the Summer Lake sub- basin during Zone 3. Used with permission Charles and Patricia Harkins. http: //sub-basin.redbubble.com/people/harkinscharles/works/7551370-klamath-marsh-big-sky.

Figure 4.3: Hippuridaceae, mare's tail. Obligate water plant, shown here flowering. The presence of the pollen of this plant in enough quantity to be counted statistically is significant, although how it was deposited inside Paisley Cave 2 is unknown at this time. Image from Digital Natural History http: //sub-basin.digitalnaturalhistory.com/flora_hippuridaceae_index.htm

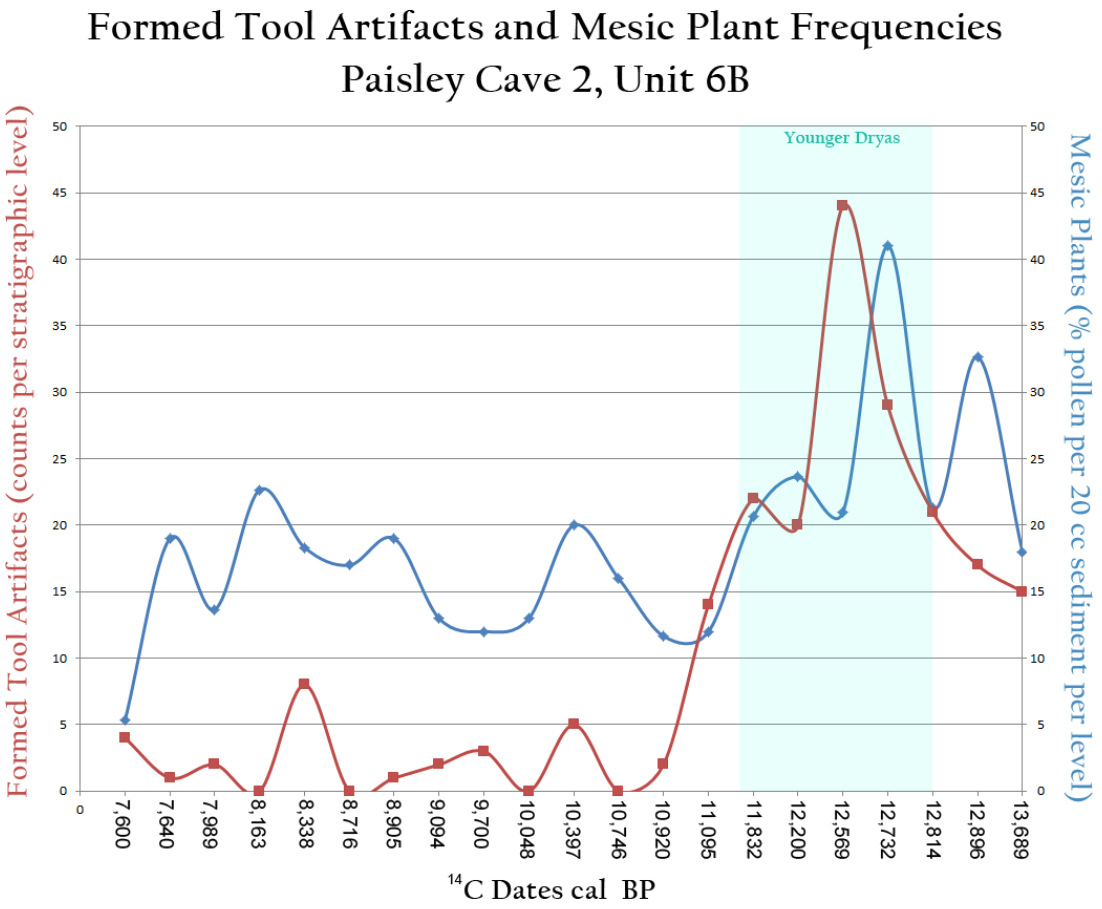

Figure 5.1: Mesic plant percentages compared to formed tool artifact counts. Younger Dryas highlighted in light blue. The chart shows a peak in mesic plants (blue line) followed by a distinct peak in formed tool artifacts (red line).

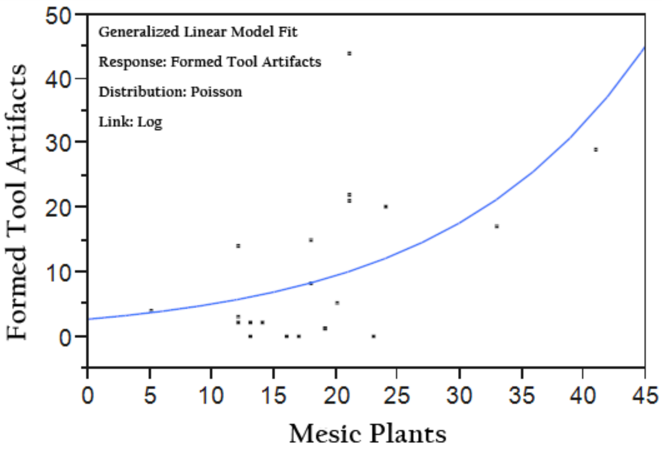

Figure 5.2: Chi squared regression, Poisson distribution. r = 67.5429, *df* = 19, p < .0001. Linear regression model tested relationship between independent lake activity (mesic plants) and dependent cultural activity (formed tool artifacts).

Tables

LUs	2012 Sample Levels	Paisley Catalog Levels	Elevation (MASL)	Ages cal BP	Notes
	Surface	Surface	1369.70	Present Day	
	1	36	1366.55-1366.52	*7,600*	Mazama
	2	37	1336.50-1366.47	**7,640**	
	3	38	1366.45-1366.42	*7,794*	
	4	39	1366.40-1366.37	*7,989*	
	5	40	1366.35-1366.32	**8,338**	
	6	41	1366.30-1366.27	*8,527*	
	7	42	1366.25-1366.22	*8,716*	
LU3	8	43	1366.20-1366.17	**9,094**	
	9	44	1366.15-1366.12	**9,700**	
	10	45	1366.10-1366.07	*9,874*	
	11	46	1366.05-1366.02	*10,048*	
	12	47	1366.00-1365.97	*10,397*	
	13	48	1365.95-1365.92	*10,746*	
Z1andZ2	14	49	1365.90-1365.87	**11,095**	Holocene
Split@14	15	50	1365.85-1365.82	*11,463*	Pleistocene
	16 **YD**	51	1365.80-1365.77	*11,832*	
LU 2-3	17 **YD**	52	1365.75-1365.72	**12,569**	
	18 **YD**	53	1365.70-1365.67	*12,650*	
LU2	19 **YD**	54	1365.65-1365.62	*12,732*	**Botanical lens**
	20 **YD**	55	1365.60-1365.57	**12,896**	
	21	56	1365.55-1365.52	**13,689**	

Table 1: Calibrated ^{14}C ages and associated stratigraphic levels and elevations. Ages obtained by ^{14}C dates shown in bold. Age range averaged estimates between the calibrated ^{14}C ages are italicized.

Surface		Zone 3			Zone 2			Zone 1		
Pinus	19%	Pinus	35-47%	39 %	Pinus	22-37%	30 %	Pinus	20-38%	28 %
		Abies	11-24%	17 %	Abies	9-25%	21 %	Abies	5-16%	9 %
				1 %	Picea	1-3%	1 %			
		Larix	2-1%		Larix	2-4%	1 %			
Cupressaceae	9%				Cupressaceae	1-3%	1 %			
		Taxaceae	1%	0 %	Taxaceae	1-3%	1 %			
		Aceraceae	1%	0 %	Aceraceae	1%	0 %			
		Betulaceae	6%	2 %	Betulaceae	2-3%	0 %			
		Alnus undif.	2-3%	2 %	Alnus undif.	1-5%	1 %	Alnus undif.	3-6%	2 %
		Betula	1-2%	1 %	Betula	2%	0 %			
Populus	2%	Populus	1-2%	1 %	Populus	1%	0 %			
		Salix	2-4%	2 %	Salix	2-14%	4 %	Salix	4-12%	7 %
					Rhamnaceae	1%	0 %			
					Grossulariaceae	2%	0 %	Grossulariaceae	2%	0 %
Quercus	2%									
					Celestraceae	1-2%	0 %	Celestraceae	1%	0 %
Artemesia	30%	Artemesia	7-16%	11 %	Artemesia	5-16%	12 %	Artemesia	10-28%	18 %
Ambrosia-type	6%	Ambrosia-type	1-4%	3 %	Ambrosia-type	1-2%	0 %	Ambrosia-type	9%	2 %
					Tubuliflorae-type	1-7%	2 %	Tubuliflorae-type	1-16%	9 %
		Caryophyllaceae	1%	0 %	Caryophyllaceae	1%	0 %	Caryophyllaceae	3%	1 %
Chenopodium-type	18%	Chenopodium-type	6-12%	6 %	Chenopodium-type	7-25%	15 %	Chenopodium-type	10-21%	16 %
Boraginaceae	1%									
								Brassicaceae	2-3%	1 %
		Brassicaceae	1-7%	2 %				Hippuridaceae	3%	1 %
Fabaceae	5%	Fabaceae	1-4%	1 %	Fabaceae	1-3%	1 %			
		Liliaceae	1-3%	2 %	Liliaceae	1%	0 %			
Linaceae	2%									
		Malvaceae	2%	1 %						
					Elaeaganaceae	1%	0 %			
Plantaginaceae	2%									
					Polygonaceae	1%	0 %			
		Onagraceae	2%	1 %	Onagraceae	1-2%	0 %			
					Spariganaceae	2%	0 %			
		Solanaceae	1-2%	1 %	Solanaceae	1-2%	0 %			
		Cactaceae	1%	0 %	Cactaceae	1%	0 %			
Typha	1%	Typha	1%	1 %	Typha	1-3%	2 %	Typha	4-2%	2 %
Poaceae	3%	Poaceae	6-9%	7 %	Poaceae	1-8%	5 %	Poaceae	6-3%	4 %
		Cyperaceae	2%	1 %	Cyperaceae	1-4%	2 %	Cyperaceae	2-1%	1 %
n=13	100%	n=24		101 %	n=31		99 %	n=16		100 %
1		4			11			6		
Exotic	3%	Exotic		3 %	Exotic		3 %	Exotic	4-6%	4 %
Mean	8%	Mean	4		Mean	3		Mean	6	
Median	3%	Median	1		Median	0		Med	2	
StDev	0.09	StDev	8.36		St.Dev.	6.93		StDev	8.18	
CV	1.18	CV	1.99		CV	2.17		CV	1.31	

Table 2: Pollen Zones taxa percentages and taxa diversity counts. Pollen zones determined by sum of square cluster analysis constrained by level. Zone 1 showed very low environmental biodiversity, with plant diversity sharply surging at the onset of the Younger Dryas period. Zone 2 exhibited the highest biodiversity of the four pollen zones with 31 plant taxa identified.

Aquatic plant indicators only as they are how lake behavior can be measured																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Dates	**7,600**	**7,640**	*7,989*	*8,163*	**8,338**	*8,716*	*8,905*	**9,094**	**9,700**	*10,048*	*10,397*	*10,746*	*10,920*	**11,095**	*11,832*	*12,200*	**12,569**	*12,732*	*12,814*	**12,896**	**13,689**
Betulacea	0	5.66667	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus unc	0	1.66667	2.33333	1.66667	3	2	0	0	2	0	5	3	0	1	2.66667	3.00	0	6.00	0	3.00	0
Betula	0	0	1	0	2.33333	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus	1.667	1.33333	0.33333	1	2	0	0	0	0	0	0	0	0	1	0.66667	0	0	0	0	0	0
Salix	0	0	2	2.33333	4	3	2	3.33333	4	3	2	2	6.33333	0	7.33333	4.00	5.00	11.00	5.00	6.00	12.00
Grossular	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2.00	0	0	0
Tubuliflor	0	0	0	0	0	1	1	0	1	0	0	5	0	1	2.33333	9.00	7.00	8.00	14.33	15.67	1.00
Brassicac	0	0	0	7	0.33333	0	0	0	0	0	0	0	0	0	0	0	0	3.00	2.00	3.00	0
Hippurida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.00	0	0	0
Typha	0.667	1.33333	0.66667	0.33333	0.66667	0	3	0.66667	1	4	2	0	3.33333	3	2.33333	2.00	3.00	4.00	0	0	0
Poaceae	3.000	7	7.33333	8.66667	6	6	6	2	4	5	8	6	1	4	4	4.67	6.00	3.00	0	3.00	5.00
Cyperace	0	2	0	1.66667	0	2	3	4	0	1	3	0	1	2	1.33333	1.00	0	1.00	0	2.00	0
Totals	5	19	14	23	18	17	19	13	12	13	20	16	12	12	21	24	21	41	21	33	18
Artifacts	4	1	2	0	8	0	1	2	3	0	5	0	2	14	22	20	44	29	21	17	15

Table 3: Mesic plant percentages and artifact counts. Paisley Caves 2, unit 6B.

Appendices

Appendix A: Pollen and exotics absolute counts.

Pollen			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Code	Name	Group																						
Pin	Pinus	TRSH	56	104	142	114	105	87	87	108	89	66	81	94	114	111	84	68	77	75	72	114	111	60
Pin	Abies	TRSH	0	69	34	33	72	72	69	60	47	108	69	57	74	72	33	28	16	21	21	48	24	33
Pin	Picea	TRSH	0	0	0	0	0	9	6	6	5	3	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Larix	TRSH	0	3	5	5	0	0	0	0	0	5	0	0	0	12	5	0	0	0	0	0	0	0
Pin	Cupressaceae	TRSH	26	0	0	0	0	0	0	0	4	6	9	6	0	0	2	0	0	0	0	0	0	0
Pin	Taxaceae	TRSH	0	0	0	3	0	0	0	0	0	6	9	2	0	0	0	0	0	0	0	0	0	0
Pin	Aceraceae	TRSH	0	4	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Pin	Betulaceae	TRSH	0	17	0	0	0	0	6	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Alnus undif.	TRSH	0	5	7	5	9	6	0	0	6	0	15	9	0	3	8	0	9	0	18	0	9	0
Pin	Betula	TRSH	0	0	3	0	7	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Populus	TRSH	5	4	1	3	6	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0
Pin	Salix	TRSH	0	0	6	7	12	9	6	10	12	9	6	6	19	0	22	43	12	15	33	15	18	36
Pin	Rhamnaceae	TRSH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
Pin	Grossulariaceae	TRSH	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
	Quercus	TRSH	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amb	Celestraceae	UPHE	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	4	0	0	0	0
Amb	Artemesia	UPHE	92	31	27	47	21	33	16	27	66	36	30	48	42	21	37	36	62	69	30	45	33	85
Amb-t	Ambrosia	UPHE	17	10	6	12	2	0	6	0	3	7	6	0	0	0	0	0	0	0	0	0	0	26
	Tubuliflorea-type	UPHE	0	0	0	0	0	3	3	0	3	0	0	15	0	3	7	21	27	21	24	43	47	3
Cryeae	Caryophyllaceae	UPHE	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	9	0	0	0	0	0
Che-t	Chenopodium-type	UPHE	54	17	18	0	36	39	51	37	48	21	27	45	21	48	70	74	65	65	54	29	34	42
	Boraginaceae	UPHE	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Braeae	Brassicaceae	UPHE	0	0	0	21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9	6	9	0
	Hippuridaceae	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0
Fabeae	Fabaceae	UPHE	16	0	4	11	0	6	8	5	0	3	3	0	0	0	0	0	0	0	0	0	0	0
Lileae	Liliaceae	UPHE	0	0	8	7	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Linaceae	UPHE	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mlveae	Malvaceae	UPHE	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elaeaganaceae	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
	Plantaginaceae	UPHE	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poleae	Polygonaceae	UPHE	0	0	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ongeae	Onagraceae	UPHE	0	0	6	0	0	0	0	0	0	0	0	0	5	0	0	4	0	3	0	0	0	0
	Spariganiaceae	UPHE	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soleae	Solanaceae	UPHE	0	5	1	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Caceae	Cactaceae	UPHE	0	0	4	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Alieae	Alismataceae	AQVP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Typ	Typha	AQVP	2	4	2	1	2	0	9	2	3	12	6	0	10	9	7	8	6	9	12	0	0	0
Poaeae	Poaceae	UPHE	9	21	22	26	18	18	18	6	12	15	24	18	3	12	12	16	14	18	9	0	9	15
Cypeae	Cyperaceae	UPHE	0	6	0	5	0	6	9	12	0	3	9	0	3	6	4	0	3	0	3	0	6	0
Lyceae	Exotic	Spore	6	11	8	7	7	12	9	8	7	6	11	5	7	6	6	8	10	12	9	16	8	14
	Total number of exotics per san		41696	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697	41697
	Sum Total		300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	Sum Trees		87	206	198	170	211	192	180	193	163	203	189	174	214	201	157	139	114	111	150	177	162	129
	Sum Herbs		204	90	100	129	87	108	111	105	134	85	105	126	76	90	136	153	180	180	138	123	138	171
	Sum Aquatic		2	4	2	1	2	0	9	2	3	12	6	0	10	9	7	8	6	9	12	0	0	0
	Concentration		2084800	1137191	1563638	1787014	1787014	1042425	1389900	1563638	1787014	2084850	1137191	2501820	1787014	2084850	2084850	1563638	1250910	1042425	1389900	781818.8	1563638	893507.1
	Concentration		104240	56859.55	78181.88	89350.71	89350.71	52121.25	69495	78181.88	89350.71	104242.5	56859.55	125091	89350.71	104242.5	104242.5	78181.88	62545.5	52121.25	69495	39090.94	78181.88	44675.36

Appendix B: Pollen counts converted to percentages.

Pollen			Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Code	Name	Group																						
Pin	Pinus	TRSH	18.667	34.66667	47.33333	38	35	29	29	36	29.66667	22	27	31.33333	38	37	28	22.66667	25.66667	25	24	38	37	20
Pin	Abies	TRSH	0	23	11.33333	11	24	24	23	20	15.66667	36	23	19	24.66667	24	11	9.333333	5.333333	7	7	16	8	11
Pin	Picea	TRSH	0	0	0	0	0	3	2	2	1.666667	1	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Larix	TRSH	0	1	1.666667	1.666667	0	0	0	0	0	1.666667	0	0	0	4	1.666667	0	0	0	0	0	0	0
Pin	Cupressaceae	TRSH	8.667	0	0	0	0	0	0	0	1.333333	2	3	2	0	0	0.666667	0	0	0	0	0	0	0
Pin	Taxaceae	TRSH	0	0	0	1	0	0	0	0	0	2	3	0.666667	0	0	0	0	0	0	0	0	0	0
Pin	Aceraceae	TRSH	0	1.333333	0	0	0	0	0	0	0	0	0	0	1.666667	0	0	0	0	0	0	0	0	0
Pin	Betulaceae	TRSH	0	5.666667	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Alnus undif.	TRSH	0	1.666667	2.333333	1.666667	3	2	0	0	2	0	5	3	0	1	2.666667	0	3	0	6	0	3	0
Pin	Betula	TRSH	0	0	1	0	2.333333	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pin	Populus	TRSH	1.667	1.333333	0.333333	1	2	0	0	0	0	0	0	0	0	1	0.666667	0	0	0	0	0	0	0
Pin	Salix	TRSH	0	0	2	2.333333	4	3	2	3.333333	4	3	2	2	6.333333	0	7.333333	14.33333	4	5	11	5	6	12
Pin	Rhamnaceae	TRSH	0	0	0	0	0	0	0	0	0	0	0	0	0.666667	0	0.333333	0	0	0	0	0	0	0
Pin	Grossulariaceae	TRSH	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
	Quercus	TRSH	2.333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amb	Celestraceae	UPHE	0	0	0	0	0	0	0	0	0	0	1	0	0.666667	0	0	0	0	1.333333	0	0	0	0
Amb	Artemesia	UPHE	30.667	10.33333	9	15.66667	7	11	5.333333	9	22	12	10	16	14	7	12.33333	12	20.66667	23	10	15	11	28.33333
Amb-t	Ambrosia	UPHE	5.667	3.333333	2	4	0.666667	0	2	0	1	2.333333	2	0	0	0	0	0	0	0	0	0	0	8.666667
	Tubuliflorea-type	UPHE	0	0	0	0	0	1	1	0	1	0	0	5	0	1	2.333333	7	9	7	8	14.33333	15.66667	1
Cryeae	Caryophyllaceae	UPHE	0	0	1.333333	0	0	0	0	0	0	0	0	0	0	0	0	0.666667	3	0	0	0	0	0
Che-t	Chenopodium-typ	UPHE	18.000	5.666667	6	0	12	13	17	12.33333	16	7	9	15	7	16	23.33333	24.66667	21.66667	21.66667	18	9.666667	11.33333	14
	Boraginaceae	UPHE	1.333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Braeae	Brassicaceae	UPHE	0	0	0	7	0.333333	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3	0
	Hippuridaceae	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Fabeae	Fabaceae	UPHE	5.333	0	1.333333	3.666667	0	2	2.666667	1.666667	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Lileae	Liliaceae	UPHE	0	0	2.666667	2.333333	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Linaceae	UPHE	2.333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mlveae	Malvaceae	UPHE	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elaeaganaceae	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.333333	0	0	0	0	0	0	0
	Plantaginaceae	UPHE	1.667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poleae	Polygonaceae	UPHE	0	0	0	0	0	1	0	1.333333	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ongeae	Onagraceae	UPHE	0	0	2	0	0	0	0	0	0	0	0	0	1.666667	0	0	1.333333	0	1	0	0	0	0
	Spariganaceae	UPHE	0	0	0	0	0	0	0	2.333333	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soleae	Solanaceae	UPHE	0	1.666667	0.333333	0	0	0	0	1.666667	0.666667	0	0	0	0	0	0	0	0	0	0	0	0	0
Caceae	Cactaceae	UPHE	0	0	1.333333	0	0	0	0	0.666667	0	0	0	0	0	0	0.666667	0	0	0	0	0	0	0
Alieae	Alismataceae	AQVP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Typ	Typha	AQVP	0.667	1.333333	0.666667	0.333333	0.666667	0	3	0.666667	1	4	2	0	3.333333	3	2.333333	2.666667	2	3	4	0	0	0
Poaeae	Poaceae	UPHE	3.000	7	7.333333	8.666667	6	6	6	2	4	5	8	6	1	4	4	5.333333	4.666667	6	3	0	3	5
Cypeae	Cyperaceae	UPHE	0	2	0	1.666667	0	2	3	4	0	1	3	0	1	2	1.333333	0	1	0	1	0	2	0
Lyceae	Exotic	Spore	2.605	4	3	3	3	4	3	3	2	2	4	2	2	2	2	3	4	3	3	6	3	6
	Sum Trees		29.000	68.66667	66	56.66667	70.33333	64	60	64.33333	54.33333	67.66667	63	58	71.33333	67	52.33333	46.33333	38	37	50	59	54	43
	Sum Herbs		68.000	30	33.33333	43	29	36	37	35	44.66667	28.33333	35	42	25.33333	30	45.33333	51	60	60	46	41	46	57
	Sum Aquatic		0.667	1.333333	0.666667	0.333333	0.666667	0	3	0.666667	1	4	2	0	3.333333	3	2.333333	2.666667	2	3	4	0	0	0
	Concentration		1568915.811	1042425	1389900	1403799	1376001	1042425	1389900	1389900	2126547	2105699	1011152	2084850	2084850	2084850	2084850	1389900	1042425	1389900	1389900	694950	1389900	694950
	Concentration			52121.25	69495	70189.95	68800.05	52121.25	69495	69495	106327.4	105284.9	50557.61	104242.5	104242.5	104242.5	104242.5	69495	52121.25	69495	69495	34747.5	69495	34747.5