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# An Examination of Western Stemmed Tradition Settlement-Subsistence, Territoriality, and Lithic Technological Organization in the Northwestern Great Basin

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# Abstract

A paucity of stratified, open-air Western Stemmed Tradition (WST) sites has long been an issue for Great Basin researchers. Most Paleoindian sites are near-surface lithic scatters that lack subsistence residues, perishable technology, and materials that can be radiocarbon dated. While surface sites pose a number of interpretive challenges, they remain essential to our understanding of WST lifeways in the Great Basin. In this dissertation, I evaluate current models of WST settlement-subsistence and lithic technological organization in the northwestern Great Basin through analyses of recently discovered and previously reported lithic assemblages. I also explore novel methods of analyzing lithic and source provenance data to strengthen interpretations of surface assemblages and source profiles. My results suggests that: (1) WST groups in the northwestern Great Basin were residentially mobile, focused on wetlands, and likely moved base camps regularly; (2) toolstone procurement strategies were based on maximizing productivity within a wetland-oriented lifestyle; and (3) the northwestern Great Basin contained a single highly connected Paleoindian network that was likely a product of unrestricted socio-political boundaries, low population densities, limited resource competition, and a mobile settlement-subsistence strategy.

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## INTRODUCTION

For nearly a century, fluted lanceolate points such as Clovis and Folsom have been the focus of discussions about the peopling of the Americas (e.g., Fagan 1995; Meltzer 2009). While fluted points may mark the arrival of people across much of North America (Meltzer 2009), they were not the only Paleoindian techno-complexes in the New World. In the Intermountain West, large stemmed and lanceolate projectile points of the Western Stemmed Tradition (WST) dominate the Terminal Pleistocene and Early Holocene (TP/EH) record (Beck and Jones 2014; Bryan 1980). While a paucity of Pleistocene-aged assemblages and megafauna kill sites has limited the role of the WST in the peopling of the Americas debate (Smith et al. 2020), discoveries at the Paisley Caves, Oregon and Cooper's Ferry, Idaho (Davis et al. 2014, 2019; Jenkins et al. 2012) suggest that the WST is contemporaneous with or older than the Clovis tradition (13,400-12,700 cal BP [Miller et al. 2014]). These findings have sparked fierce debate (e.g., Beck and Jones 2014; Fiedel 2014; Fiedel and Morrow 2012; Goebel and Keene 2014) and brought the WST to the forefront of Paleoindian research (Smith et al. 2020).

While the WST has a rich history of research in the Intermountain West, there are still many aspects of WST lifeways we do not understand. A primary issue is that stratified sites are rare, especially those in open-air contexts. Most sites are near-surface lithic scatters that lack subsistence residues, perishable technology, and means to reliably date the assemblages. In the Great Basin, where WST sites are plentiful, archaeologists have primarily relied upon lithic and source provenance data derived from surface assemblages to explore Paleoindian settlement-subsistence, territoriality, trade, and technological organization (e.g., Beck and Jones 2010; Elston et al. 2014; Jones et al. 2003; Reaux et al. 2018; Smith 2010, 2011). Although these studies are foundational to our understanding of WST lifeways, the interpretive challenges (e.g., limited chronological control) of surface assemblages has limited our ability to confidently answer many of the questions that drive WST research. Nevertheless, until we discover more stratified sites, surface assemblages will remain essential. For now, a primary challenge for Great Basin researchers is finding new ways to analyze surface sites to gain new insights into WST lifeways.

In this dissertation, I evaluate current models of WST settlement-subsistence and lithic technological organization in the northwestern Great Basin through analyses of recently recorded and existing assemblages. I explore novel methods of analyzing lithic and source provenance data to expand and strengthen our interpretations of surface assemblages and source profiles.

## The Western Stemmed Tradition in the Great Basin

The Great Basin is a vast internally-draining region of North America’s Intermountain West (Figure 1.1). The region is known for its desert environments and basin and range topography. Today’s Great Basin is very different from that of the TP/EH. In general, the Terminal Pleistocene (~16,000-11,600 cal BP) was cooler and wetter than the current Holocene climatic period (~11,600 cal BP to present). Most valleys contained pluvial lakes and wetlands (Grayson 2011). Pine and juniper forests and sagebrush steppe also grew at lower elevations (Wigand and Rhode 2002). Megafauna such as mammoths (*Mammuthus* sp.), camels (*Camelops* sp.) and horses (*Equus* sp.) roamed the landscape although their populations were probably limited due to a lack of abundant grasslands (Grayson 2016). The end of the Younger Dryas period (~11,600 cal BP) marked the onset of the warmer and dryer Early Holocene (Grayson 2011). During this time, many of the region's pluvial lakes began to desiccate. While some lakes completely disappeared, others became shallow and productive wetlands (Adams et al. 2008; Grayson 2011). Forests and sagebrush steppe also retreated to higher elevations and megafauna were already extinct. By the onset of the Middle Holocene, many lakes and wetlands had disappeared across the Great Basin (Grayson 2011). For the remainder of this section, I discuss WST technology, chronology, distribution, and settlement-subsistence in the Great Basin.

### *Technology*

During the late 1930s, archaeologists Elizabeth and William Campbell and geologist Ernst Antevs argued that stemmed point groups inhabited the Mohave Desert during the TP/EH (Campbell et al. 1937); however, their claim was undermined by a lack of absolute dating techniques at the time. Following the advent of radiocarbon dating, some archaeologists (e.g., Cressman 1951; Bedwell 1973; Bryan 1980) developed stronger claims that stemmed points dated to the TP/EH in the Intermountain West. As research expanded across the region, it became clear that stemmed points possessed a considerable amount of morphological and temporal variability (Amsden 1937; Butler 1965; Daugherty 1956; Layton 1968, 1970; Leonhardy and Rice 1970; Rice 1965; Rice 1972; Tuohy 1969, 1974; Tuohy and Layton 1977; Warren 1967). Tuohy and Layton (1977) were the first to formally organize stemmed point types by placing them under the umbrella category of the Great Basin Stemmed Series (GBSS). However, they envisioned the GBSS as a temporary taxonomic device and did not equate the GBSS to any broader cultural context. Shortly after Tuohy and Layton (1977) coined the GBSS, Alan Bryan (1980), in an effort to organize the rapid accumulation of new stemmed points sites and morphologies, assigned TP/EH stemmed points across the Intermountain West into the Stemmed Point Tradition, now commonly referred to as the WST.

Stemmed projectile points are the hallmark of the WST. Although researchers have proposed numerous WST point varieties since Campbell et al.'s (1937) formulation of the first stem point types, only seven have seen widespread acceptance (Figure 1.2 [see Beck and Jones 2009, 2015]). These include Lake Mohave and Silver Lake (Amsden 1937), Parman and Cougar Mountain (Layton 1968, 1970, 1972), Haskett (Butler 1965), Lind Coulee (Daugherty 1965), and Windust (Leonardy and Rice 1970; Rice 1965; Rice 1972). Some geographically restricted and less widely accepted forms include Bonneville (Duke 2011) and Stubby (Beck and Jones 2015; Schmitt et al. 2007). While efforts have been made to develop an objective typology for WST points (e.g., Beck and Jones 2009, 2015), they have largely proven unsuccessful given the amount of morphological overlap between types (but see Davis et al. 2017 and Hartman 2019).

The source(s) of morphological variation among WST points remains unclear. Given the similarities in overall shape, Beck and Jones (2009) explored whether smaller WST point types were the product of reworking larger point forms. While some evidence supported this idea, they found that most smaller points could not be the product of reworking larger points. Lafayette and Smith (2012) tested if different point types served different functions; for example, as projectile tips and knives. Through a replicative experiment and use-wear analysis, they concluded that WST points, regardless of type, were used as both projectiles and as butchering tools. Thus, functional differences were likely not the cause of morphological variability. Rosencrance (2019, see also Beck and Jones 1997) recently explored the possibility that different WST point types date to different intervals within the broader TP/EH. He found support that temporal differences may explain some, but not all, of the variability.

In general, WST lithic technology is biface-oriented and tools are made of a variety of raw materials such as obsidian, fine-grained volcanics (FGV), and cryptocrystalline silicates (CCS) (Beck and Jones 2014). WST groups commonly manufactured projectile points and bifaces from flake blanks produced from unidirectional, multidirectional, centripetal, and amorphous cores (Beck and Jones 2010; Davis et al. 2012; Skinner 2018; Smith et al. 2019). Bifaces often possess broad collateral flaking but other flaking patterns such as parallel oblique, irregular, and parallel collateral also occur (Beck and Jones 2009, 2015). Points often have lenticular cross-sections and edge grinding along stem margins (Beck and Jones 2009, 2015). Crescents are also diagnostic of the WST and they commonly appear in assemblages near wetlands (Sanchez et al. 2016). Their function is unknown, but they may have served as cutting tools or projectile points used to stun waterfowl (Beck and Jones 2014). While the sample of crescents from dated contexts is small, the data suggests that WST groups used them throughout the TP/EH (Smith et al. 2014). Beyond bifaces, the WST toolkit contains a variety of flake tools such as side and end scrapers, gravers, and retouched flakes. Unlike the Clovis tradition, blade technology was not a primary component of the WST (Beck and Jones 2014). Although WST groups sometimes used ground stone implements, they are uncommon compared to later assemblages and people probably used them to process roots, game, and pigment more than seeds (Herzog and Lawlor 2016).

WST technology is relatively similar across the Great Basin; however, some point types do appear to be tied to specific areas (see Figure 1.1). Haskett, Windust, and Cougar Mountain types most commonly occur in the northwestern and eastern Great Basin. Lake Mohave and Silver Lake types frequently appear in the southern, central, and eastern regions but are rare in the northwest (Rosencrance 2019). Parman points are found throughout the Great Basin. Lind Coulee types are generally restricted to the Columbia Plateau and Snake River Plain but some may exist in the northwestern Great Basin (Rosencrance 2019). Bonneville and Stubby types are restricted to the eastern Great Basin (Beck and Jones 2015). Crescents are present across the entire region (Beck and Jones 2014; Sanchez et al. 2017).

WST groups also used a variety of fiber, osseous, wood, and shell tools and ornaments. Fiber artifacts include cordage, nets, footwear, bags, mats, and baskets (Connolly et al. 2016). People made textiles using various methods such as Catlow twining, diagonal twining, plain twining, and plaiting (Camp 2017; Connolly et al. 2016). Bone and wood implements include bone needles, awls, and fishhooks as well as wooden foreshafts, pegs, and points from WST components at sites like the Paisley Caves (Jenkins et al. 2014), Last Supper Cave (Felling 2015), and Danger Cave (Jennings 1957). Finally, marine shell beads occur in some WST assemblages. Ethnographically, Great Basin groups used shell beads for jewelry and decorating clothes (Stern 1998; Stewart 1941). At the LSP-1 Rockshelter in Oregon, Smith et al. (2016) found five *Olivella* shell beads dated to ~9600-8100 cal BP. Based on stable isotope analysis, Smith et al. (2016) concluded that the shells likely originated along the Oregon or Washington coasts.

### *Chronology*

Securely dated WST assemblages are largely restricted to caves and rockshelters, although some dated open-air sites do exist (Goebel and Keene 2014; Rosencrance 2019; Smith et al. 2020). The age of the WST has been a major point of contention among researchers in recent years (Goebel and Keene 2014; Beck and Jones 2014; Fiedel 2014; Manning 2020) due to the discovery of possible pre-Clovis WST occupations at the Paisley Caves, Oregon (Jenkins et al. 2012). The most significant finds were coprolites possessing human DNA and a textile fragment securely dated to ~14,000 cal BP, nearly a thousand years before Clovis (Gilbert et al. 2008; Goebel and Keene 2014; Jenkins et al. 2012, 2014; Shillito et al. 2020). Jenkins et al. (2012) also reported WST point fragments in association with dates ranging between 13,285 and 12,690 cal BP. Minimally, these findings place the WST as contemporaneous with Clovis (13,400-12,700 cal BP [Miller et al. 2014]), calling into question long-standing models of the peopling of the Americas.

Some researchers have challenged Jenkins et al.'s (2012) results by criticizing the origin of the coprolites and the stratigraphic integrity of the site (e.g., Fiedel 2014; Goebel and Keene 2014; Goldberg et al. 2009); however, a recent human fecal biomarker analysis (Shillito et al. 2020) confirmed the human origin of some coprolites dating to ~14,000 cal BP.

Additional support for a pre-Clovis or at least contemporary-with-Clovis WST has now appeared at several sites. At Cooper's Ferry, Idaho, Davis et al. (2014, 2017, 2019, 2020; see also Manning 2020) reported WST material in association with a date range of 13,610-13,275 cal BP; however, they also reported cultural material in association with a date range of 16,580-15,280 cal BP. If Davis and colleagues' interpretations are correct and their oldest dates can be securely associated with WST points, the WST will stand as the oldest well-defined techno-complex in the Americas. At Bonneville Estates Rockshelter in eastern Nevada, Goebel and Keene (2014, see also Graf 2007) suggested that the earliest WST occupations were likely between 12,600 and 12,410 cal BP but that they could be as old as 12,900 cal BP, coeval with Clovis. A recently published radiocarbon date on an ecofact from Smith Creek Cave, Nevada suggests that it may also contain Clovis-aged WST material (Smith et al. 2020) although additional work is needed to more confidently associate the date with WST material. While none of these sites are without issue, the amount of data suggesting that the WST is contemporaneous with or older than Clovis is growing. Although Smith et al. (2020) recently suggested the beginning of the WST in the Intermountain West likely began around ~13,000 cal BP, the new dates reported for Paisley Caves (Shillito et al. 2020) and

Cooper’s Ferry (Davis et al. 2019) indicate that the WST may have arrived in the Americas as early as 16,560 cal BP.

Sites like the Paisley Caves and Cooper’s Ferry suggest that the WST developed and/or arrived in the Far West during the Terminal Pleistocene; however, most (~70%) WST sites date to the Early Holocene (~11,500-8300 cal BP) (Beck and Jones 1997; Rosencrance 2019; Smith et al. 2020). As such, the WST primarily flourished as a late Paleoindian techno-complex (Goebel et al. 2014). Around the onset of the Middle Holocene (~8300 cal BP) WST technology disappeared across the Intermountain West (Grayson 2011). In sum, the WST tentatively dates to between ~14,000 and 8300 cal BP although the early date range may extend to ~16,560 cal BP if future research can securely associate the early Cooper’s Ferry’s dates with WST material.

### *Distribution*

WST sites are mostly restricted to the Intermountain West (Pratt 2020) but similar tools occur elsewhere in western North America. On California’s Channel Islands, TP/EH assemblages contain both stemmed points and crescents, although they are somewhat different than those from the Intermountain West (Erlandson 2011). Evidence of stemmed point assemblages along the coast of British Columbia is also emerging (McLaren et al. 2019). Roughly contemporary stemmed point forms such as Agate Basin, Hell Gap, Alberta, and Cody are widespread across the Great Plains. In general, these types are thought to be independent from the WST due to significant differences in point morphologies and subsistence strategies (Hartman 2019); however, some researchers (e.g., Amick 2013; Hartman 2019; Rosencrance 2019) have suggested that the WST and Great Plains stemmed traditions may be related and that groups moved between regions during the TP/EH. Importantly, stemmed point traditions are older in the Intermountain West (Hartman 2019), ruling out the possibility that Plains groups brought the technology into the region.

In the Great Basin, WST sites are fairly common in open-air settings near relict TP/EH wetlands but early groups also occupied some caves and rockshelters. Upland occupations mostly date to the Early Holocene and may reflect a response to declining wetland availability (Grayson 2011). While WST lifeways are generally similar across the Great Basin, some sub-regional differences in occupation intensity and age do exist (Grayson 2011; Jones et al. 2003, 2012; Rosencrance 2019). The northwestern Great Basin (see Figure 1.1) contains the earliest WST occupation at the Paisley Caves, Oregon where WST material dates to ~14,000-12,690 cal BP (Jenkins et al. 2012; Shillito et al. 2020). In the nearby Fort Rock Basin, sites such as Cougar Mountain Cave (Jamaldin 2018; Rosencrance et al. 2019) and the Connley Caves (Jenkins et al. 2017) contain evidence of Younger Dryas occupations. Other notable northwestern Great Basin sites such as Last Supper Cave (Felling 2015), Hanging Rock Shelter (Grayson 1988; Smith et al. 2011), the Paulina Lake Site (Connolly 1999), and the LSP-1 Rockshelter (Smith et al. 2016), possess Early Holocene assemblages (see Smith and Barker 2017 for a review of dated TP/EH sites in the northwestern Great Basin). This region also contains a substantial WST surface record. The Parman Localities (Layton 1970; Smith 2007), Catnip Creek Delta (CCD) Locality (Reaux et al. 2018), North Warner Valley (Smith et al. 2015), and Hawksy Walksy Valley (Bradley et al. 2020; Christian 1997) each possess dense concentrations of WST material associated with wetland and riparian habits.

The eastern Great Basin (see Figure 1.1) also contains numerous WST sites. Bonneville Estates Rockshelter in eastern Nevada (Goebel and Keene 2014; Graf 2007) currently represents the only possible pre-Younger Dryas aged site in the region (~12,900 BP) although Goebel and Keene (2014) argue the most definitive WST occupations began there between 12,600 and 12,410 cal BP. Younger Dryas-aged sites include Smith Creek Cave (Smith et al. 2020), Danger Cave (Jennings 1957), and the Wishbone Site (Duke et al. 2019). The Sunshine Locality in eastern Nevada (Beck and Jones 2009) and the Old River Bed Delta in western Utah (Duke 2011; Madsen et al. 2015) contain the largest concentrations of WST material in the Great Basin.

The WST record of the southern and central Great Basin (see Figure 1.1) is not well understood. Securely-dated sites are rare and only a few well-documented WST assemblages exist (e.g., Basgall and Hall 1993; Fenner 2011; Jenkins 1991). Research in these regions suggests that most WST occupations occurred during the Early Holocene (Beck and Jones 1997; Rosencrance 2019). For example, the Roger’s Ridge Site in southeastern California contained Lake Mohave points associated with a date range of 11,095-10,200 cal BP (Jenkins 1991), whereas the Awl Site possessed Parman and Silver Lake points dating between 10,125-8655 cal BP (Basgall and Hall 1993). The Mud Lake Basin (Fenner 2011) in southern Nevada contains large quantities of WST and fluted points, suggesting that Paleoindian groups did frequently visit some areas in the south-central Great Basin but finding early occupations in datable contexts remains a challenge.

### *Subsistence*

Large projectile points suggest that WST groups targeted large game but there is little direct evidence for megafauna hunting in the Great Basin (Goebel et al. 2011; Grayson 2016; Smith and Barker 2017). While possible evidence of megafauna hunting and/or scavenging does exist (Cressman 1942; Duke 2015; Goebel et al. 2011; Grayson 2016; Jenkins et al. 2014), WST groups likely did not habitually hunt megafauna because they were never abundant in the region (Grayson 2016). Because most sites are near-surface lithic scatters much of what we know about WST diet comes from dry caves and rockshelter sites. Sites such as Last Supper Cave (Grayson 1988), LSP-1 (Pellegrini 2014), Paisley Caves (Hockett et al. 2017), Bonneville Estates Rockshelter (Goebel et al. 2011; Hockett 2007), and Smith Creek Cave (Goebel et al. 2011) contained faunal assemblages dominated by rabbits and hares, birds, rodents, fish, and shellfish. Artiodactyls such as pronghorn, mule deer, and big horn sheep occur in some assemblages but often in low frequencies.

WST groups also supplemented their diet with a variety of plants and insects (Goebel et al. 2011; Hockett et al. 2017). At the Bonneville Estates Rockshelter, Rhode and Louderback (2007) found that Early Holocene groups ate cactus pads and a variety of seeds (e.g., sunflower, Indian Ricegrass). Coprolites from the Paisley Caves (Jenkins et al. 2014) and the Spirit Cave Mummy (Tuohy and Dansie 1997) and starch grain residue analyses of Early Holocene ground stone and textiles (Herzog and Lawlor 2016) also demonstrate that Paleoindians incorporated various roots and seeds into their diets. While stable isotope analysis of the Buhl Woman showed a diet primarily of anadromous fish, her heavily worn teeth suggest that she also ate foods processed with milling stones (Green et al. 1998). Ultimately, the paucity of stratified open-air sites, where most kill/butchering sites should be found (Grayson 2011), has probably led to a biased understanding of WST diet. Regardless, caves and rockshelter assemblages demonstrate that WST groups had a broad diet similar to Middle and Late Holocene groups.

### *Settlement-subsistence and Mobility*

Archaeologists have long recognized the importance of wetlands to WST lifeways (e.g., Beck and Jones 2003; Bedwell 1973; Campbell et al. 1937; Duke and King 2014; Elston et al. 2014; Madsen 2007; Napton 1969; Pinson 1999; Willig 1989; Wriston and Smith 2017; Young 1995); however, the manner in which groups used these places remains a central question to WST research. Bedwell's (1973) Western Pluvial Lakes Tradition (WPLT) represented the first major effort to model TP/EH settlement-subsistence. At Fort Rock Cave and the Connolly Caves, Oregon, Bedwell (1973) found stemmed points associated with waterfowl bones. He argued that people occupied the caves as conditions grew warmer and drier, which increased the number of wetlands and prompted a focus on marsh resources. He also noted that stemmed points from those sites were similar to those that Campbell et al. (1937) found along the shores of Lake Mohave in the southern Great Basin. Based on these observations, Bedwell (1973) proposed that Paleoindians were largely tethered to wetlands. While the WPLT established the important relationship between WST groups and wetlands, it did not acknowledge that WST sites also occurred in a variety of other settings (Pinson 1999; Willig 1989).

Over the past few decades, researchers have developed new models that better account for variability in WST site location. Starting in the 1980s, many researchers turned to the growing field of human behavioral ecology (HBE [Bettinger et al. 2015]) to examine Paleoindian settlement-subsistence in the Great Basin (e.g., Elston et al. 1995; O'Connell et al. 1982; Pinson 1999; Simms 1987). In recent years, Elston and Zeanah (2002) have explored the role that a sexual division of labor played in TP/EH settlement-subsistence strategies (see also Elston et al. 1995). Drawing on patch-choice and diet-breadth models, Elston and Zeanah (2002) proposed that residential camp locations reflected a compromise between the foraging goals of men and women. Groups placed base camps near wetlands so women could forage for plants, waterfowl, and small game while men could hunt artiodactyls in the surrounding low to mid-elevation brushy steppe. Because wetland habitats were abundant and populations were low, Paleoindians could have remained mobile to optimize men's encounter rates with large game without impeding women's foraging interests. Elston et al. (2014) later revised this model, suggesting the foraging strategies were less sexually divergent than they initially envisioned. Because artiodactyl encounters were probably high near wetlands, they argued that men and women should have hunted together until return rates fell to the point at which it was more optimal for women to shift to collecting small game and plants. If return rates fell far enough then the entire group would relocate to another basin (Elston et al. 2014).

In addition to HBE modeling, some archaeologists have turned to toolstone source provenance studies to explore WST settlement-subsistence and mobility (Beck and Jones 2003, 2012; Madsen 2007; Newlander 2012; Reaux et al. 2018; Smith 2010). Jones et al.

(2003, 2012) developed the lithic conveyance zone (LCZ) concept, which utilized the distances and directions that people conveyed toolstone, to delineate WST foraging ranges. They argued that LCZs represented the territories of groups who practiced high residential mobility and primarily targeted high-ranked resources. They attributed this settlement-subsistence strategy to the changing TP/EH climatic conditions and variable abundance and quality of resources across the region.

Some researchers (e.g., Madsen 2007; Newlander 2012; Smith 2010; Smith and Harvey 2018) have challenged Jones et al.'s (2003, 2012) methods and interpretations. Madsen (2007) argued that WST settlement-subsistence strategies were likely variable and influenced by wetland size and quality. He suggested that groups likely practiced long-distance movements and short-term residential occupations in areas characterized by small and/or unproductive wetlands. In regions with large and productive wetlands, groups were probably more residentially stable. Madsen (2007) argued that Jones et al.'s (2003) LCZs could reflect both strategies. Newlander (2012, 2015, 2018) analyzed the conveyance of different toolstone types such as obsidian, FGV, and CCS in eastern Nevada and found that they reflected LCZs of different sizes. He argued that the smaller FGV/CCS zones likely represented the actual foraging ranges of WST groups whereas the much larger obsidian zones reflected social networks. Smith and Harvey (2018) later demonstrated that the LCZ concept is undermined by issues of equifinality and sampling bias.

While there remains no consensus about WST settlement-subsistence and mobility strategies, most models tend to fall into two categories. The first proposes that groups maintained a residentially mobile lifestyle consisting of short stays and frequent moves between wetlands (Elston et al. 2014; Jones et al. 2003, 2012; Newlander 2012; Smith 2010). The second proposes that some WST groups were more residentially stable, established longer-term camps near wetlands, and relied on a logistical system to provision their camps (Madsen 2007). Ultimately, the lack of stratified open-air sites containing food remains and other organic items amendable to radiocarbon dating makes it difficult to definitively determine which of these models best represent WST settlement-subsistence strategies. Furthermore, there may not have been a single WST adaptation. Given the limitations of LCZ modeling and paucity of stratified open-air sites, we must find new ways to analyze and interpret surface assemblages and source provenance data. This dissertation represents a step in that direction.

## Research Outline

As this introduction has highlighted, there are a number of unanswered questions about the Great Basin's earliest inhabitants. Foremost among them are: (1) how much territory did WST groups traverse during seasonal, annual, or lifetime movements; (2) how did they use wetlands; and (3) how did they acquire and convey toolstone. Although researchers have made considerable contributions to these topics (e.g., Beck and Jones 2003; Bedwell 1973; Jamaldin 2018; Layton 1970; Pinson 1999; Smith 2010, 2011; Willig 1989), the research I outline in the coming chapters expands upon their ideas. These chapters, formatted as journal article manuscripts to be submitted for consideration, highlight novel methods, datasets, and theoretical orientations to build upon our current understanding of WST lifeways. Chapter 2 reconstructs the technological activities that people carried out at the CCD Locality in Guano Valley, Oregon, which represents one of the densest concentrations of WST material in the Great Basin (Reaux et al. 2018). Chapter 2 also provides a detailed understanding of settlement-subsistence strategies and lithic technological organization at the CCD Locality, expanding our understanding of TP/EH lifeways in the northwest Great Basin.

Chapter 3 presents a test of a lithic gravity model that examines the influence that geologic and geographic factors had on WST lithic procurement strategies at the CCD Locality. While source provenance studies (e.g., Jones et al., 2003, 2012; Madsen 2007; Newlander 2012; Smith 2010) have helped to identify which toolstone sources WST groups used and how they may have conveyed raw materials, few have explicitly addressed why people selected those materials in the first place. The gravity model approach offers a novel way to analyze source provenance data and provides a means to assess current debates about WST settlement/subsistence (Smith and Harvey 2018).

Chapter 4 examines WST territoriality, site connectivity, and socioeconomic interactions through a social network analysis of WST and Early Archaic sites across the northwestern Great Basin. The impetus for this study came from differences in the WST source profiles of neighboring Guano and Warner valleys (Reaux et al. 2018; Smith et al. 2015). Groups in the CCD Locality appear to have procured most raw materials from sources in northwestern Nevada and northeastern California, whereas groups in North Warner Valley primarily obtained raw materials in central Oregon. I use network analysis methods to determine if these patterns represented the presence of multiple regional lithic networks during the TP/EH. I also explore the overall connectivity of WST sites in the region and how lithic and social networks changed during the Early-Middle Holocene transition. This study marks the first use of network analysis methods in the Great Basin and provides a way past some of the limitations of the LCZ concept.

Finally, Chapter 5 summarizes major findings of my research efforts. I synthesize my results and discuss their broader impacts on our understanding of WST settlement-subsistence strategies and technological organization in the northwestern Great Basin. Lastly, I explore various avenues for future research that can improve and add to the studies presented here.

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Figure 1.1. The Hydrographic Great Basin and sub-regions described in the text.

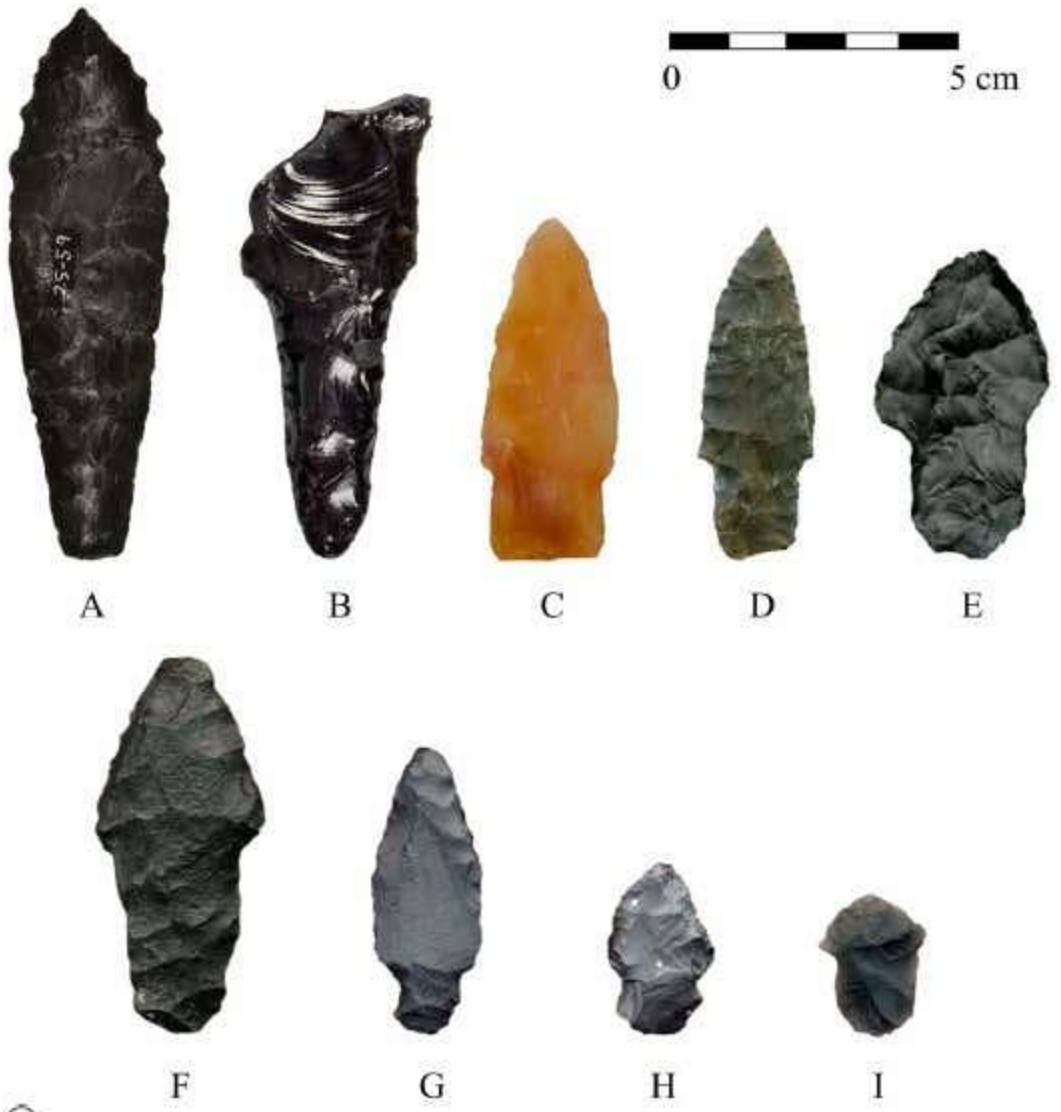

Figure 1.2. Western Stemmed Tradition point types: (A) Haskett; (B) Cougar Mountain; (C) Windust; (D) Lind Coulee; (E) Parman; (F) Lake Mohave; (G) Bonneville; (H) Silver Lake; and (I) Stubby. Figure adapted from Smith et al. (2020) with permission from the authors.

# Chapter 2:

# WESTERN STEMMED TRADITION SETTLEMENT-SUBSISTENCE AND LITHIC TECHNOLOGICAL ORGANIZATION IN THE CATNIP CREEK DELTA, GUANO VALLEY, OREGON

*Cave and rockshelter sites have long been the cornerstone of Western Stemmed Tradition (WST) research across the Great Basin; however, these sites likely offer a narrow view of Terminal Pleistocene and Early Holocene lifeways. Open-air sites dominate the WST record and are critical to our understanding of WST settlement-subsistence practices and technological organization. I present the results of a lithic, source provenance, and spatial analysis of the Catnip Creek Delta (CCD) Locality, Guano Valley, Oregon. The CCD Locality contains one of the densest concentrations of Paleoindian artifacts in the region. My results indicate that the CCD Locality WST assemblage is likely a product of numerous short-term occupations by residentially mobile groups who primarily used the location to replenish their lithic toolkit and as a hunting location.*

## Introduction

Much of what we know about the Western Stemmed Tradition (WST) (~13,500-8300 cal BP) in the Great Basin comes from caves and rockshelters that contain preserved hearth features, subsistence residues, and textiles (Grayson 2011; Smith and Barker 2017; Smith et al. 2019). Cave and rockshelter occupations were often ephemeral and task oriented (e.g., hunting and/or processing) and thus offer a narrow view of Paleoindian lifeways (Jamaldin 2018; Smith and Barker 2017). Most WST sites (see Beck and Jones 2009; Hildebrandt et al. 2016; Madsen et al. 2015; Smith 2007; Smith et al. 2015) are near-surface lithic scatters in open-air settings that lack datable materials and are likely palimpsests, which pose interpretive problems (e.g., limited chronological control). Given that intact stratified open-air sites are rare, these surface assemblages remain critical to furthering our understanding of early lifeways. In this paper, I present the results of a lithic, source provenance, and GIS-based spatial cluster analysis of the Catnip Creek Delta (CCD) Locality, Guano Valley, Oregon (Figure 2.1). The CCD Locality contains one of the densest concentrations of Terminal Pleistocene/Early Holocene (TP/EH) artifacts in the Great Basin, consisting of over 600 diagnostic Paleoindian tools within a small (~20 km$^2$) delta system (Reaux et al. 2018). I use these data to test hypotheses about WST settlement-subsistence and lithic technological organization in the CCD.

## Background

### *Western Stemmed Tradition Settlement-subsistence Models*

Most researchers agree that WST groups were mobile and focused on wetlands (Elston et al. 2014; Grayson 2011; Smith et al. 2020), although how, when, and why they moved residential camps is debated (Duke and Young 2007; Jones et al. 2003; 2012; Madsen 2007; Newlander 2012; Smith and Harvey 2018). One popular WST model, which I refer to here as the *Wetland Transient Model*, holds that WST groups were residentially mobile and frequently relocated their camps between wetlands (Elston and Zeanah 2002; Elston et al. 2014; Jones et al. 2003, 2012; Smith 2010). This model posits that it was more efficient for groups to move camp than undertake long-distance logistical forays or broaden their diets in wetland locales. This model is supported by multiple lines of evidence. First, Paleoindian sites generally lack evidence of longer-term occupations such as residential structures, storage features, or midden accumulations (Elston et al. 2014). Second, lithic sourcing data demonstrate that Paleoindians conveyed toolstone, presumably as they traveled, over great distances (Jones et al. 2003, 2012; Reaux et al. 2018; Smith 2010; but see Newlander 2012). Third, WST lithic technology features a generalized and portable toolkit of large bifacial tools that likely served as both hunting and butchering implements (Beck and Jones 2009; Lafayette and Smith 2012). Finally, WST sites are often small, contain just a handful of tools, and are generally associated with relict wetlands.

A second model, which I refer to as the *Wetland Stable Model*, suggests that WST groups placed longer-term residential basecamps around wetlands, possibly moving only a few times per year, and acquired some resources (e.g., toolstone, large game) through long-distance logistical forays (Madsen 2007; Willig 1989). Elston and Zeanah (2002) suggest that groups situated their basecamps near wetlands so women could forage near camp while men ventured into the uplands to hunt and gather additional resources (but see Elston et al. 2014). Madsen (2007) argues that long-distance logistical forays could produce large lithic conveyance zones and that increased residential stability should not be discounted.

The recent discovery of substantial surface Paleoindian records in Guano Valley (Reaux et al. 2018) and Hawksy Walksy Valley (Bradley et al. 2020; Christian 1997), as well as WST residential structures at the Paulina Lake Site (35DS34 [Connolly and Jenkins 1999]) and the Parman Localities (Hildebrandt et al. 2016), suggest that early groups in the northwestern Great Basin may have been more residentially stable than previously thought (Jones et al. 2003, 2012; Smith 2010; Smith and Barker 2017). Such discoveries present an opportunity to critically evaluate WST settlement-subsistence models in the region.

### *Analyzing Surface Assemblages*

Researchers (e.g., Andrefsky 1994; Beck et al. 2002; Binford 1980; Kuhn 1995) have devised various methods to make sense of surface assemblages. For example, site function can be examined by analyzing the types, density, and diversity of stone implements in an assemblage. The types of bifaces and debitage found at a site can provide insights about settlement and subsistence strategies. In general, sites representing residential mobility systems should possess the byproducts of tool manufacturing, maintenance, and discard, whereas in logistical systems much of the biface reduction process happened at special purpose sites away from camp (Beck et al. 2002; Binford 1980). Additionally, residentially mobile groups often used more formal (intentionally shaped) than informal (unmodified flakes) lithic tools due to the constraints imposed by a mobile lifestyle. As groups decreased their residential mobility, there was often a distinct shift to assemblages reflecting higher numbers of informal flake tools (Andrefsky 1994;

Kelly 2001; Kuhn 1994; Parry and Kelly 1987); however, Andrefsky (1994) notes that if toolstone was plentiful then these patterns may not hold true (see also Kuhn 1995).

A common method for analyzing lithic assemblages is to calculate unhafted biface to core and formal to informal tool ratios (Andrefsky 1994; Felling 2015; Parry and Kelly 1987). Because bifaces can be used as efficient cores, many researchers believe that they were a central component of mobile tool kits (Kelly 1988; Kelly and Todd 1988; Kuhn 1995; but see Prasciunas 2007). Conversely, residentially stable groups were not constrained by frequent camp relocations and could have relied on non-bifacial cores to produce informal tools as needed (Andrefsky 1994). Artifact diversity can also provide insight into site use. For example, Shott (1986) found that longer residential occupations tend to produce more diverse assemblages. In sum, longer-term residential occupations should produce tool assemblages that are large and diverse and possess low formal to informal and unhafted biface to core ratios (Figure 2.2).

Toolstone source provenance research has also furthered our understanding of WST lifeways (Hughes 1984; Jones et al. 2003, 2012; Newlander 2012, 2015; Smith 2010). While this research can effectively tell us which toolstone sources people used, the limited spatial and chronological control of surface assemblages often makes it difficult to discern exactly how toolstone was conveyed or what source profiles actually represent (Jones et al. 2012; Madsen 2007; Smith and Harvey 2018). Despite these issues, source profiles provide valuable data about possible foraging ranges, group movements, socioeconomic interactions, and connections between sites (Jones et al. 2012; Newlander 2012; Reaux et al. 2018).

Source profiles can also be used to calculate local to non-local toolstone (L/NL) ratios. Local to non-local toolstone ratios offer a way to measure relative occupation span at surface sites (Kuhn 1995; Smith 2011; Surovell 2009). This approach assumes that when groups first occupy an area, their tools will be made from materials acquired elsewhere (what Schiffer [1975] referred to as the *founder* set). Over time these tools will be exhausted and replaced with those made using local material (Schiffer's *donor* set). As occupation span increases, those tools made on local material will also become exhausted and replaced using additional local material. Thus, sites that possess high proportions of local toolstone suggest longer stays whereas sites with high proportions of non-local toolstone suggest shorter stays (but see Young 1989). Researchers (e.g., Reaux et al. 2018; Smith 2007, 2008) commonly calculate L/NL ratios using time sensitive projectile points to mitigate temporal control issues with surface assemblages. Local to non-local toolstone ratios only tell us if one site was occupied for more or less time than another site; however, that is still useful information in many instances.

### *Guano Valley and the Catnip Creek Delta*

Guano Valley is a small lake basin that straddles the Oregon-Nevada border (see Figure 2.1). Despite a brief visit by Luther Cressman (1936), the valley's natural and cultural history was largely unknown to professional archaeologists until recently. During the 2016 and 2017 field seasons, the University of Nevada, Reno's Great Basin Paleoindian Research Unit (GBPRU) conducted archaeological and paleoenvironmental research in Guano Valley. To gain an understanding of the valley's hydrological history, GBPRU crews recorded important geologic features across the valley (Reaux et al. 2018). Unlike most basins in the region, Guano Valley does not possess distinctive erosional shorelines that correspond to pluvial lake stands. Instead, the basin contains a single shoreline at ~1585-1586 m above sea level (masl). Elevation measurements taken across the playa surface suggest that Pluvial Lake Guano was shallow and ranged between ~2-4 m in depth during wet periods. The lake likely remained shallow throughout the Terminal Pleistocene and Holocene due to a low sill at the north end of the valley that allowed water to flow into Catlow Valley via an outflow channel known as Guano Slough (Reaux et al 2018).

Several intermittent creeks drain into Guano Valley but the most substantial source of freshwater comes from Catnip Creek that has an extensive channel system at the southern end of the valley (Figure 2.3). We call this area the Catnip Creek Delta. The delta, which is characterized by a low gradient and numerous meandering or anastomosing channels (~0.5-2 m in depth), covers ~20 km$^2$. Because the elevation of Pluvial Lake Guano was controlled by a low sill, much of the delta was likely never inundated. Given this fact, parts of the delta likely fostered stable riparian habitats during the TP/EH. We placed five backhoe trenches across channels in the CCD but did not find datable material that could provide a better understanding of the delta’s hydrological history. The CCD system lacks substantial evidence of subsequent fluvial or eolian erosion, which suggests that the archaeological sites there are likely in their original depositional contexts (Reaux et al. 2018). The delta’s archaeological integrity is further evident with the presence of TP/EH artifacts distributed across the lower portion of a large alluvial fan debouching from Stateline Canyon, immediately east of the CCD. A large rock outcrop at the mouth of the canyon currently diverts water and alluvial deposits to the north and south of the artifact concentrations. Based on the presence of WST artifacts across its distal surface (Figure 2.4), the fan appears to represent a Terminal Pleistocene or older landform that has not played a significant role in burying or shifting artifacts into secondary contexts.

The impetus for this project was not only to fill in a gap in the region's TP/EH record, but to also help place the GBPRU's work in neighboring North Warner Valley (Smith et al. 2015; Wriston and Smith 2017), just west of Guano Valley, into a broader context. During our initial visits, GBPRU crews performed targeted surveys on features that commonly contain TP/EH sites (e.g., lakeshores [Elston et al. 2014; Grayson 2011; Wriston and Smith 2017]). We identified only a few isolated WST points (*n*=9) and numerous Archaic sites around Guano Lake. This prompted a shift to southern Guano Valley where we discovered a substantial WST record along the channel system. We finished work in Guano Valley in 2017 after completing a full survey and collection of the CCD and the areas immediately adjacent to it.

The CCD Locality produced over 600 temporally diagnostic TP/EH artifacts and 1970 bifaces, flake tools, and cores. Paleoindian artifacts are three times as abundant as Archaic artifacts (Table 2.1). Most artifacts were concentrated in a small portion of the delta just north of the Oregon-Nevada border on United States Fish and Wildlife Service (USFWS) land. Much of the delta south of the border has been flooded by a historic reservoir constructed by the IXL Ranch (USFWS 2012). Artifacts found along the reservoir's margins suggest that the extensive surface record was once present throughout the entire system including the now flooded meadow (Figure 2.5). Finally, we identified an abundant cobble source of Massacre Lake/Guano Valley (ML/GV) obsidian emerging from the alluvium and surrounding hillslopes at the southern end of the CCD and, to a lesser extent, within the channels themselves.

## Materials and Methods

For this study, I used WST projectile points, crescents, and most other lithic artifacts collected within or directly adjacent to the CCD. Although fluted and unfluted concave base points are present (*n*=1 and 16, respectively), their relationship to the WST remains unclear (Beck and Jones 2009, 2014) and I do not extensively discuss them here. While the CCD record undoubtedly represents multiple occupations that span the Holocene, I included all bifaces, cores, and flake tools given the dominance of WST material and lack of a means to separate potential later occupations. I excluded all discernable Archaic artifacts (i.e., dart and arrow points) from my sample.

### *Lithic and Source Provenance Analyses*

To gain an understanding of the nature of WST occupations in the CCD, I conducted a typological and technological analysis of all collected tools and debitage. I assigned WST projectile points to recognized types following Beck and Jones (2009, 2015, and references therein). I separated unhafted bifaces into early, middle, late (preforms), and finished stages following Smith's (2006; see also Andrefsky 1998) work with WST assemblages from the nearby Parman Localities. I also classified formal and informal flake tools and cores following Smith (2006). During fieldwork, we recorded the CCD Locality as a series of individual sites given the density of material and land ownership requirements (the CCD is managed by multiple federal agencies). At each site, we collected all flakes from within a minimum of two 2-x-2-m areas. I classified debitage using a standard typology developed by the GBPRU which includes the following types: decortication, core reduction, biface thinning, pressure, flake fragment, and shatter (see Smith 2006 for descriptions).

I geochemically characterized most obsidian and FGV artifacts from the CCD Locality using an Olympus Delta DP-6000 portable X-ray fluorescence unit[1] housed at the GBPRU laboratory. I sent 11 artifacts made of materials that did not match those in our comparative collection to the Northwest Research Obsidian Studies Laboratory (NWROSL) for characterization. I incorporated nearly all formal/informal tools and 30 flakes from each cluster in the CCD Locality (see below). In each debitage sample, I included equal numbers of randomly selected decortication, core reduction, biface thinning, and pressure flakes when possible. For L/NL ratios, I considered ML/GV obsidian to be the only local obsidian for Guano Valley. Elsewhere (Reaux et al. 2018), I previously considered Badger Creek and Beatys Butte obsidian as well as Coyote Springs FGV as local. Although I found these toolstone types in the CCD as single, unmodified, small cobbles, further investigations in 2019 did not identify additional examples of those materials; therefore, their availability is not widespread enough to include them as locally available sources.

To calculate diversity within the assemblage, I used Simpson's Reciprocal Index (Heip et al. 1998). Simpson's Reciprocal Index considers both richness and evenness and provides a score between 1 and the total number of artifact types in a sample. I used five artifact types to calculate diversity: unhafted bifaces, hafted bifaces (WST points, crescents), informal flake tools (retouched flakes), formal flake tools (scrapers), and cores. Higher values represent greater overall diversity. I calculated unhafted biface to core ratios by dividing the count of unhafted bifaces by the number of cores in each assemblage. Finally, I determined formal to informal tool ratios by dividing formal tools counts (bifaces, points, scrapers) by the number of informal flake tools (retouched flakes only).

### *Spatial Analysis*

Surface sites present both temporal and spatial analytical challenges. Although finding debitage-free areas within the CCD is difficult, we noticed clusters of tools while in the field. Because these clusters may represent temporally/spatially discrete occupations or activity areas, I conducted a spatial analysis using the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) tool within ArcGIS Pro to remove the arbitrariness of the sites we recorded (Environmental Systems Research Institute 2020). The DBSCAN tool identifies clusters of data points and outliers based on a set search radius and defined cluster size. For this analysis, I used a 30-m search radius to separate clusters (based on the common distance used in cultural resource management projects) and a minimal cluster size of six tools (based on the smallest recorded site). A portion of the CCD Locality is represented by a continuous ~1 km span of artifacts that I could not adequately separate using the DBSCAN tool. I did not include these artifacts in the spatial analysis.

## Hypotheses and Expectations

Western Stemmed Tradition groups may have used the CCD in several ways including as: (1) a short-term residential camp; (2) a population aggregation location; (3) a long-term residential camp; and/or (4) a toolstone procurement site. These kinds of use should produce lithic assemblages that differ in important ways.

*H1 (Wetland Transient Model: Short-term Residential Camp)*. The CCD record represents numerous short-term occupations within a larger residentially mobile settlement system (*sensu* Jones et al. 2003). This hypothesis suggests that WST groups did not prefer to stay in the CCD for long and/or that it was not productive enough to foster long-term occupations. Because the clusters should reflect short-term camp locations or activity areas, I expect each to possess:

1. Low local to non-local toolstone ratios;
2. Biface and debitage types that reflect tool production and maintenance;
3. Largely similar source profiles;
4. A limited flake tool assemblage;
5. Low tool diversity; and
6. High biface to core and formal to informal tool ratios.

*H2 (Wetland Transient Model: Aggregation Location for Transient Groups)*. The CCD record represents a central place for otherwise dispersed mobile groups (*sensu* Madsen 2007). This hypothesis suggests that the density and variety of resources available in the CCD made it an ideal place for groups to periodically congregate to exchange goods, find mates, perform rituals, conduct communal hunts, and/or socialize. The clusters may signify individual or repeated aggregation events. I expect each cluster to possess:

1. Low local to non-local toolstone ratios;
2. Source profiles that are represented by a variety of sources coming from different areas in generally similar frequencies; and
3. A moderate to large flake tool assemblage (potentially skewed towards food processing activities).

*H3 (Wetland Stable Model: Long-term Residential Camp)*. The CCD record represents long-term occupations within a residentially stable/logistically mobile system. The clusters represent activity areas or locations where groups relocated their camps periodically. I expect each cluster to possess:

1. A very high local to non-local toolstone ratio;
2. Biface and debitage types that reflect tool production and maintenance;
3. Similar source profiles;

4. A large flake tools assemblage;
5. High tool diversity; and
6. Low unhafted biface to core and formal to informal tool ratios.

*H4 (Wetland Stable Model: Logistical Destination)*. The CCD record reflects numerous short-term logistical lithic procurement forays. This hypothesis suggests that WST groups visited the CCD just to acquire toolstone. I expect each cluster to possess:

1. A high non-local to local toolstone ratio;
2. Biface and debitage types skewed towards early/middle stage biface production (*sensu* Beck et al. 2002);
3. A source profile that may lack clear patterning or conversely possess strong directional patterning;
4. A small flake tool assemblage;
5. Low tool diversity; and
6. High biface to core and formal to informal tool ratios.

## Results

I identified 11 distinct clusters of artifacts in the CCD (see Figure 2.4). While I present clusters 2, 8, and 11 in tables 2.2 and 2.7, I do not include them in the analysis because they were small and lacked WST artifacts. Cluster size ranges from 34 to 408 total tools. Differences in cluster size may reflect varying occupation spans, group sizes, and/or number of individual occupation events that took place at those spots.

### *Lithic Analysis*

Tables 2.2 and 2.3 show the distribution of artifacts across each cluster, the entire CCD Locality, and comparable WST sites in the region. Unhafted bifaces make up 65% of the CCD Locality assemblage (*n*=1669) and dominate all but one cluster (Cluster 7=45%). Late stage and finished bifaces are the most prevalent types although middle stage bifaces are also common (Figure 2.6). Early stage bifaces make up just 7% of the unhafted bifaces. This trend in biface type distribution is present in all clusters.

Projectile points are the second most prevalent tool type (23%, *n*=606). They include 566 WST projectile points, 23 crescents, 16 unfluted concave base points, and one fluted point (figures 2.6 and 2.7). Roughly half of the WST points are basal stem fragments. Specific WST types are present in the assemblage. Short-stem Parman points are most common (*n*=35) followed by long-stem Cougar Mountain points (*n*=16) and short-stem square-based Windust (*n*=15) types. Haskett points are present but rare.

Rosencrance's (2019) study of WST points from dated contexts suggests that Parman and Cougar Mountain types in the northwestern Great Basin date to the Early Holocene (~11,400-8800 cal BP). Likewise, Rosencrance (also see Hartman 2019) found that Windust points generally date to the end of the Early Holocene. The substantial presence of these point types in the CCD Locality may signal that it was primarily occupied during the Early Holocene. In general, Parman and Cougar Mountain points are evenly distributed within the clusters, suggesting that the clusters date to the same general, though likely broad, period.

Formal and informal flake tools are uncommon, making up just 3% and 7% of the total assemblage, respectively. Most flake tools are expedient retouched flakes. Formal flake tools include 82 scrapers consisting mostly of various side and end-scraper types (see Smith 2007). Flake tools make up ~10% of most cluster assemblages with retouched flakes often outnumbering scrapers. I did not find any unique patterning of formal or informal flake tools within or between clusters (e.g., dense concentrations of scrapers), suggesting that similar activities may have taken place in each area.

Formal cores are also uncommon in the CCD (*n*=41, 2%). Most (~65%) cores are simple flake cores but centripetal (*n*=2) and prismatic cores (*n*=2) are also present (see Smith 2007 for core descriptions). I analyzed a total of 3113 flakes across the CCD (Table 2.4). Decortication, core reduction, and biface thinning flakes are present in roughly equal proportions (16-20%). Pressure flakes are rare (3%) but this may be a product of post-depositional processes. The proportions of these flake types are consistent across clusters.

### *Source Provenance Analysis*

Tables 2.5-2.7 present the CCD Locality source profiles. Tools were primarily made of obsidian (93% of the total assemblage) followed by FGV (6%) and cryptocrystalline silicates (CCS [1%]). Debitage consists of 98% obsidian with CCS and FGV each making up just 1%. Thirty-six unique geochemical types are represented

(Figure 2.8). Projectile points are the most toolstone rich artifact class with 34 unique geochemical types. Unhafted bifaces are also quite rich at 29 geochemical types followed by flake tools (*n*=15) and cores (*n*=5). Early and middle stage bifaces are less geochemically rich than their late and finished counterparts. A small portion of the tool assemblage (~4%) could not be assigned to known geochemical types. Many of these artifacts were manufactured of FGV, the sources of which are not well documented in the region.

Locally available ML/GV obsidian comprises 64% of the tool assemblage from the CCD and is the dominant material type across all tool classes. Non-local toolstone sources range from 21 to 250 km from the CCD (see Figure 2.8). The most distant sources are represented solely by WST points, indicating that they were conveyed over long distances. Beatys Butte obsidian, the most common non-local toolstone, makes up just 7% of the tool assemblage. This obsidian is ~46 km north of the CCD in the northeastern most part of Guano Valley and into southern Catlow Valley. Excluding Beatys Butte obsidian, most (~19%) exotic toolstone originates from sources in Nevada's High Rock Country and California's Warner Mountains south and southwest of Guano Valley. This pattern is visible across all clusters suggesting those source locations were the last to be visited before groups arrived at the CCD. The debitage source profile supports this possibility: ~85% of flakes sourced to ML/GV and all non-local flakes sourced to Beatys Butte or sources to the south/southwest.

Table 2.8 displays the L/NL ratios for WST tools from the CCD and other sizable WST sites in the northwestern Great Basin. The CCD Locality's WST toolstone ratio is lower than those of other surface sites and cave/rockshelter occupations. The L/NL ratios for WST clusters are also generally lower than other regional WST sites but groups appear to have occupied some areas longer than others (i.e., clusters 7 and 10). Overall, the CCD Locality toolstone ratios suggest that WST groups generally occupied the delta for less time than many sites in the northwestern Great Basin.

### *Tool Ratios and Assemblage Diversity*

Unhafted biface to core ratios for the CCD Locality are very high, with a score more than double those of WST residential sites such as Parman Locality 3, Paulina Lake, and of Last Supper Cave (see Table 2.3). This pattern holds across all clusters except 7 and 10. Likewise, the CCD Locality formal to informal tool ratios are over twice those for comparable WST sites (see Table 2.3). Clusters 7 and 10 remain exceptions, with smaller overall values. Finally, Reciprocal Simpson Index values (5=high diversity) are generally low to moderate across the clusters with an overall value of 2.1. This value is lower, albeit not considerably, than comparable WST residential sites. This is not surprising given that unhafted bifaces comprise 65% of the assemblage.

## **Discussion**

The results of these lithic, spatial, and source provenance analyses paint a relatively clear picture of WST activity in the CCD. The lithic assemblage generally reflects: (1) low L/NL toolstone ratios; (2) a toolkit dominated by unhafted bifaces and Early Holocene WST points; (3) mostly early stage production debitage; (4) limited intercluster variability in tool diversity and source profile; (5) a small and homogenous flake tool assemblage; (6) low to moderate tool diversity; (7) high unhafted biface to core and formal to informal tool ratios; and (8) a combined source profile that suggests groups came to the CCD from northeastern California/northwestern Nevada and the Beatys Butte area. These trends closely fit the expectations for Hypothesis 1: the CCD record represents numerous short-term occupations within a larger residentially mobile settlement system (Wetland Transient Model).

High unhafted biface to core and formal to informal tool ratios, low L/NL toolstone ratios, limited tool diversity, and a small flake tool assemblage together suggest that the CCD Locality was used for short-term stays, although some stays may have been longer than others (i.e., clusters 7 and 10). The two well-published open-air WST sites containing house structures, Parman Locality 3 (Hildebrandt et al. 2016; Smith 2007) and the Paulina Lake Site components 1-2 (Connolly and Jenkins 1999), have higher quantities of flake tools (30-40%) compared to the CCD Locality (10%). These sites also possess generally lower unhafted biface to core and formal to informal tool ratios, as well as more diverse toolkits (Figure 2.9). Surprisingly, L/NL toolstone ratios for those sites and the CCD Locality are similar (see Figure 2.9). One possible explanation for the similar ratios is that ML/GV obsidian covers a vast area south/southwest of Guano Valley and is also found near other large WST sites like the Parman Localities (Smith 2007, 2010). Groups may have manufactured some of the CCD Locality’s ML/GV artifacts at sources other than Guano Valley, which would give the appearance of greater local toolstone use and, in turn, longer occupations than was actually the case (this may also be true for the Parman Localities). Overall, the Paulina Lake and Parman Locality 3 assemblages suggest that groups used those sites differently and for longer periods than the CCD, but despite the presence of residential features it is likely that these sites still reflect relatively short-term occupations (perhaps only a season or less [Connolly and Jenkins 1999]). Nevertheless, if Parman Locality 3 and the Paulina Lake Site are representative of longer WST residential occupations, then the CCD Locality assemblage does not meet the expectations for Hypothesis 3 (Wetland Stable Model).

Across all clusters, the same handful of toolstone types comprise 70% or more of characterized artifacts. These include Beatys Butte obsidian and multiple sources that lie south/southwest of Guano Valley between 21 and 72 km away. Similar source profiles characterize nearby Hanging Rock Shelter (Smith et al. 2011), Last Supper Cave (Felling 2015; Smith 2008), the Parman Localities (Layton 1970; Smith 2007; 2010), and Hawsky Walksy Valley (Christian 1997). Source profiles from North Warner Valley (Smith et al. 2015) and the Fort Rock Basin (Jamaldin 2018), both to the northwest, are different and reflect a primary focus on central Oregon sources; however, both the CCD Locality and North Warner Valley assemblages possess numerous sources from central Oregon and northwest Nevada’s High Rock Country. In Chapter 4, I suggest that these locations may represent common stopping places for mobile WST groups moving between the two sub-regions of the northwestern Great Basin. Although the consistent presence of Beatys Butte (a northern source) obsidian alongside High Rock Country sources suggests a possible coming together of groups in the CCD Locality, the general characteristics of the assemblage (e.g., mostly biface manufacturing) do not provide strong evidence that this was the case (Hypothesis 2). It is more plausible that this pattern is the product of separate occupations of the CCD Locality by WST groups moving south from central Oregon and north from the High Rock Country.

The abundance of unhafted bifaces and stemmed point fragments suggests that WST groups commonly used the CCD for biface production and retooling. The prevalence of late stage and finished bifaces suggests that the site was not simply a logistical toolstone procurement destination (Hypothesis 4). While some of the CCD record is certainly attributable to later occupations, the relative lack of groundstone (*n*=7) and features suggests that people used the area similarly throughout the Holocene. Interestingly, nearly half of all finished bifaces are distal blade tips. Most finished blade fragments likely represent WST points because they are often large and possess lenticular cross-sections and broad-collateral flaking patterns (see Beck and Jones 2009, 2015). Finished blade fragments are often found at kill sites (Hockett 2009); however, they can also be found at residential camps when transported back in animal carcasses (Amick 1996) or when broken during manufacture. In addition to retooling, groups may have also used the CCD as a hunting location and implemented an intercept strategy. Elston et al. (2014) argue that riparian areas along drainages entering a valley are particularly attractive to migrating artiodactyls in search of forage and water. In Railroad Valley, Nevada, they found that TP/EH sites clustered along such drainages. Other large WST sites have been recorded in similar environments across the Great Basin at locations such as the Sunshine Locality (Beck and Jones 2009), Old River Bed Delta (Madsen et al. 2015), and North Warner Valley (Smith et al. 2015). Furthermore, we observed pronghorn, mule deer, and bighorn sheep descending into the CCD to graze during fieldwork. This was likely also the case throughout the Holocene.

The availability of toolstone, fresh water, and small and large game suggests the CCD was an ecotone: a location where habitats with various resources overlap (*sensu* Pinson 2007). The CCD Locality record supports Pinson's (2007) claim that substantial TP/EH sites in the northwestern Great Basin should be found in such places. Although the delta provides numerous resources, it may not have been as productive as we originally assumed. Ethnographically, women in the Great Basin provided the bulk of a group's diet through small seeds, geophytes, and tree nuts (Kelly 1932; Zeanah 2004). While intensive plant processing is not evident during the TP/EH, large game hunting success in ethnographic foraging societies is rarely fruitful enough to provide a group's daily caloric and nutritional needs (Kelly 1932; Kelly 2013). Despite the availability of water, large game, and toolstone, there simply may not have been enough other reliable food resources to permit long-term occupations. Our fieldwork supports this notion given that grinding stones were prevalent around the lake margins but all but absent within the CCD itself. Instead, the delta may ultimately have served as a reliable hunting and retooling waystation for groups moving between more productive habitats.

## Conclusion

Reaux et al. (2018) previously suggested that the CCD record was likely a product of a stable and productive riparian habitat that fostered long stays by early groups. This was an intuitive assumption based on the sheer volume of lithic detritus found on the delta. In light of the results presented here, the CCD Locality may actually represent the opposite. Low L/NL toolstone ratios, a homogenous assemblage dominated by late stage/finished bifaces, and generally high unhafted biface to core and formal to informal tool ratios do not support the delta's use as an area of population aggregation (Hypothesis 2), a long-term logistical basecamp (Hypothesis 3), or as a logistical destination (Hypothesis 4). Instead, these observations show that the CCD record represents numerous short-term occupations within a larger residentially mobile settlement system (Hypothesis 1: Wetland Transient Model). If our assumptions about lithic technological organization are correct, then the CCD record appears to signify repeated short-term, Early Holocene occupations by WST groups focused on biface manufacturing and hunting. Finally, the similarities between the assemblages and source profiles of the CCD Locality, the Parman Localities (Layton 1970; Smith 2007), Hanging Rock Shelter (Smith et al. 2011), Last Supper Cave (Felling 2015; Smith 2008), and Hawksy Walksy Valley (Christian 1997) suggest that these sites are associated with similar WST groups, who ranged throughout the northwestern Great Basin (see Chapter 3) and practiced a mobile lifestyle characterized by short-stays and frequent moves between the region's numerous and productive wetlands.

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## Notes

[1] The Delta model uses a 40 kV Rhodium (Rh) anode X-Ray tube and Olympus Innov-X Systems software. We employed the fundamental parameters calibration provided by the Innov-X software and ran our device using the two-beam (40 and 10 kV) GeoChem mode at 60 seconds per beam. To build our comparative collection, we initially characterized nearly 1000 previously sourced artifacts analyzed by the NWROSL between 2004 and 2013. Over 60 geochemically distinct obsidian/ FGV types from the northwestern Great Basin are represented in that sample. Additionally, over the last five years we visited known obsidian and FGV source locations around the northwestern Great Basin to collect geologic samples to build a more robust comparative collection. Our comparative collection currently contains over 90 geochemically distinct obsidian and FGV types from our study area. To make source assignments, we initially analyzed ratios (in parts per million) of the Mid-Z elements strontium (Sr), zirconium (Zr), niobium (Nb), yttrium (Y), and rubidium (Rb) using bivariate scatterplots with R software. With the growth of our comparative collection, we have transitioned to statistically assigning all sources using discriminant function analysis in the FORDISC program (Pilloud et al. 2017). To assess the accuracy of our in-house assignments using these methods, we submitted 43 previously uncharacterized artifacts from the Parman Localities (Smith 2007) to the NWROSL for geochemical characterization. Our source assignments of those artifacts matched the NWROSL's source assignments perfectly, indicating that our results are very accurate.

Table 2.1. Frequencies of Analyzed Diagnostic Artifacts in the CCD Locality Assemblage.

| **Artifact Type**[a] | **n** |
|---|---|
| WST Points | 566 |
| Crescents | 23 |
| Fluted Points | 1 |
| Unfluted Concave Base Points | 16 |
| Northern Side-notched Points | 31 |
| Elko Series Points | 75 |
| Humboldt Points | 24 |
| Gatecliff Series Points | 31 |
| Rosegate Series Points | 39 |
| Desert Series Points | 2 |
| **Total** | 808 |

[a] I classified Middle and Late Holocene points using Thomas' (1981) Monitor Valley Key.

Table 2.2. Tool Type Distribution and Ratios for the CCD Locality Clusters.

| | **Cluster Number** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tool Type** | **C-1** | **C-2** | **C-3** | **C-4** | **C-5** | **C-6** | **C-7** | **C-8** | **C-9** | **C-10** | **C-11** | **CCD (All)** |
| Early Stage Biface | 1 | 1 | 15 | 2 | 4 | 12 | 1 | | 2 | 9 | - | 115 |
| Mid-Stage Biface | 5 | 1 | 21 | 9 | 7 | 35 | 12 | 3 | 9 | 23 | 1 | 349 |
| Late Stage Biface | 8 | - | 56 | 16 | 28 | 96 | 18 | 1 | 8 | 27 | 1 | 531 |
| Finished Biface | 1 | - | 66 | 16 | 19 | 77 | 5 | 5 | 4 | 12 | 1 | 496 |
| Biface Fragment | 2 | - | 35 | 5 | 8 | 26 | 3 | 1 | 2 | 1 | 1 | 178 |
| WST Point | 15 | 3 | 70 | 35 | 24 | 113 | 29 | - | - | 15 | 1 | 566 |
| Crescent | 1 | - | 1 | - | 1 | 4 | 1 | - | - | - | - | 23 |
| Retouched Flake | 1 | 1 | 21 | 4 | 6 | 24 | 14 | 2 | 4 | 21 | 3 | 178 |
| Scraper | - | - | 12 | 5 | 4 | 14 | 1 | 2 | 1 | 4 | - | 82 |
| Core | - | - | 5 | 1 | - | 7 | 2 | - | - | 8 | - | 41 |
| Concave Base Point | - | - | 2 | - | - | - | - | - | - | 2 | - | 16 |
| Fluted Point | - | - | - | - | - | - | - | - | - | - | - | 1 |
| **Total** | **34** | **6** | **304** | **93** | **101** | **408** | **86** | **14** | **30** | **122** | **8** | **2576** |
| | | | | | | | | | | | | |
| **Unhafted Biface to Core Ratio** | **-** | - | 38.6 | 48 | - | 35.1 | 19.5 | - | - | 9 | - | 40.7 |
| **Formal to Informal Tool Ratio** | 32 | 5 | 13.1 | 22 | 15.7 | 15.5 | 4.9 | 6 | 6.5 | 4.3 | 1.7 | 13 |
| **Reciprocal Simpson Index** | 2.2 | 3.8 | 2.1 | 2.5 | 2.0 | 2.2 | 2.9 | 1.7 | 1.4 | 2.5 | 3.1 | 2.1 |

Table 2.3. Tool Distribution and Ratios for WST Residential Sites in the Northwestern Great Basin.

| | **Site** | | | |
|---|---|---|---|---|
| **Tool Type** | **LSC White Stratum** | **LSC Lower Shell Stratum** | **Parman Locality 3** | **Paulina Lake Components 1 and 2** |
| Early Stage Biface | 7 | 3 | 14 | 20 |
| Mid-Stage Biface | 11 | 11 | 21 | 60 |
| Late Stage Biface | 7 | 3 | 16 | 19 |
| Finished Biface | 2 | 3 | 11 | - |
| WST Point | 12 | 14 | 44 | 27 |
| Retouched Flake | 108 | 90 | 24 | 111 |
| Scraper | 22 | 13 | 21 | 6 |
| Core | 11 | 20 | 3 | 8 |
| Concave Base Point | - | - | 2 | - |
| **Total** | **180** | **157** | **156** | **251** |
| | | | | |
| **Unhafted Biface to Core Ratio** | 2.5 | 1 | 20.7 | 12.4 |
| **Formal to Informal Tool Ratio** | 0.7 | 0.6 | 5.3 | 1.2 |
| **Reciprocal Simpson Index** | 2.5 | 2.7 | 3.5 | 2.8 |

Note: LSC=Last Supper Cave; CCB=Concave Base.

Table 2.4 CCD Locality Debitage.

| | Cluster Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Material Type** | **C-1** | **C-3** | **C-4** | **C-5** | **C-6** | **C-7** | **C-10** | **CCD (All)** |
| Obsidian | 60 | 344 | 208 | 296 | 376 | 204 | 154 | 3037 |
| FGV | - | 1 | 1 | 6 | 5 | 4 | - | 31 |
| CCS | - | 2 | - | 2 | 5 | 12 | 1 | 37 |
| Basalt | - | - | 1 | 1 | 2 | 2 | - | 8 |
| | | | | | | | | |
| **Debitage Type** | | | | | | | | |
| Decortication | 11 | 57 | 41 | 47 | 144 | 15 | 38 | 611 |
| Core Reduction | 9 | 61 | 58 | 59 | 59 | 23 | 34 | 526 |
| Biface Thinning | 11 | 61 | 44 | 54 | 32 | 47 | 28 | 512 |
| Pressure | 1 | 7 | 6 | 16 | 7 | 20 | 7 | 88 |
| Fragment | 28 | 159 | 60 | 129 | 144 | 115 | 46 | 1361 |
| Shatter | - | 1 | 1 | - | 2 | 1 | 1 | 12 |
| Overshot | - | 1 | - | - | - | 1 | - | 2 |
| **Total** | 60 | 347 | 210 | 305 | 388 | 222 | 155 | 3113 |

Table 2.5. Source Profile for Diagnostic Paleoindian Artifacts in the CCD Locality.

| | | Projectile Point Type | | | | |
|---|---|---|---|---|---|---|
| **Toolstone Source** | **Distance to Source (km)[a]** | WST | Crescent | CCB | Fluted | **Total** |
| Alturas | 66 | 6 | - | - | - | 6 |
| Badger Creek | 24 | 31 | 1 | 3 | - | 35 |
| Beatys Butte | 46 | 82 | 2 | - | - | 84 |
| Beatys Butte B | 46 | 2 | 1 | 1 | 1 | 5 |
| Blue Spring | 68 | 4 | - | - | - | 4 |
| BS/PP/FM[b] | 72 | 7 | - | - | - | 7 |
| Buck Mountain | 62 | 25 | 3 | 1 | - | 29 |
| Cowhead Lake | 45 | 44 | - | - | - | 44 |
| Coyote Spring | 44 | 13 | 1 | - | - | 14 |
| Coyote Wells | 222 | 1 | - | - | - | 1 |
| Double H/Whitehorse[b] | 121 | 9 | - | - | - | 9 |
| Double O | 139 | 2 | - | - | - | 2 |
| Drews Creek/Butcher Flat[b] | 111 | 1 | - | - | - | 1 |
| GF/LIW/RS[b] | 191 | 2 | - | - | - | 2 |
| Glass Buttes | 181 | 5 | - | - | - | 5 |
| Hawks Valley | 27 | 18 | - | - | - | 18 |
| Horse Mountain | 137 | 7 | - | - | - | 7 |
| Indian Creeks Butte | 170 | 1 | - | - | - | 1 |
| Long Valley | 18 | 10 | 2 | 1 | - | 13 |
| Massacre Lake/Guano Valley[b] | <1 | 188 | 10 | 8 | - | 206 |
| Mosquito Lake | 31 | 29 | - | - | - | 29 |
| Quartz Mountain | 191 | 1 | - | - | - | 1 |
| Rainbow Mines | 68 | 5 | - | - | - | 5 |
| Riley | 165 | 2 | - | - | - | 2 |
| Spodue Mountain | 140 | 1 | - | - | - | 1 |
| Sugar Hill | 71 | 4 | - | - | - | 4 |
| Surveyor Springs | 39 | 6 | - | - | - | 6 |
| Tank Creek | 161 | 1 | - | - | - | 1 |
| Unknown | n/a | 15 | - | - | - | 15 |
| Unknown FGV 1[c] | n/a | 4 | - | - | - | 4 |
| Unknown Obsidian 1[c] | n/a | 11 | 1 | - | - | 12 |
| Venator FGV | 236 | 1 | - | - | - | 1 |
| Wagon Tire | 152 | 2 | - | - | - | 2 |
| Warner Valley FGV | 89 | 1 | - | - | - | 1 |
| Whitewater Ridge | 250 | 1 | - | - | - | 1 |
| **Total Artifacts** | - | 542 | 21 | 14 | 1 | 578 |
| **Total Sources** | - | 34 | 8 | 5 | 1 | 34 |

Note: CCB=concave base, BS/PP/FM=Bordwell Springs/Pinto Peak/Fox Mountain, GF/LIW/RS=Grasshopper Flats/Lost Iron Well/Red Switchback.

[a] Euclidean distances measured from CCD to nearest known source for each raw material type.

[b] Sources with multiple names and/or locations but are geochemically indistinguishable.

[c] Geochemically distinct sources with unknown geographic locations.

Table 2.6. Source Profile for Non-diagnostic Artifacts in the CCD Locality.

| | | **Tool Type** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Toolstone Source** | **Distance to Source (km)[a]** | Early Stage Biface | Mid-Stage Biface | Late Stage Biface | Finished Biface | Biface Fragment | Ret. Flake | Scraper | Core | **Tool Total** | **Debitage Total** |
| Alturas | 66 | 1 | 1 | 6 | 2 | 1 | - | 1 | - | 12 | - |
| Badger Creek | 24 | 3 | 6 | 13 | 18 | 6 | 2 | 1 | - | 49 | 2 |
| Beatys Butte | 46 | 3 | 15 | 21 | 33 | 8 | 6 | 3 | 1 | 90 | 4 |
| Beatys Butte B | 46 | 1 | - | - | - | - | - | - | - | 1 | - |
| Blue Spring | 68 | - | - | 1 | 1 | - | - | - | - | 2 | - |
| BS/PP/FM | 72 | 1 | - | 3 | 6 | - | - | - | 1 | 11 | 2 |
| Buck Mountain | 62 | - | 4 | 3 | 8 | 3 | 1 | - | - | 19 | 1 |
| Buck Spring | 82 | - | - | 2 | - | - | 1 | - | - | 3 | - |
| Cowhead Lake | 45 | - | 1 | 13 | 19 | 5 | 1 | 4 | - | 43 | 4 |
| Coyote Spring | 44 | 4 | 7 | 8 | 4 | 6 | 5 | 8 | 4 | 46 | 3 |
| Craine Creek | 61 | - | 2 | 1 | 1 | - | - | - | - | 4 | - |
| Double H/Whitehorse | 121 | - | 1 | 2 | - | - | - | 1 | - | 4 | - |
| Glass Buttes | 181 | - | - | 2 | 1 | - | 1 | - | - | 4 | - |
| Hawks Valley | 27 | 2 | 4 | 8 | 6 | 1 | 2 | - | - | 23 | - |
| Horse Mountain | 137 | - | - | 1 | - | - | - | 3 | - | 4 | - |
| Indian Creeks Butte | 170 | - | - | - | - | 1 | - | - | - | 1 | - |
| Long Valley | 18 | - | 2 | 6 | 4 | - | 1 | 1 | 1 | 15 | - |
| MLGV | <1 | 88 | 258 | 356 | 282 | 103 | 125 | 39 | 31 | 1282 | 175 |
| Mosquito Lake | 31 | 1 | 5 | 9 | 16 | 1 | 1 | 2 | - | 35 | 1 |
| Quartz Mountain | 191 | - | - | 1 | - | - | - | - | - | 1 | - |
| Rainbow Mines | 68 | - | - | - | 2 | - | 1 | - | - | 3 | - |
| Spodue Mountain | 140 | - | - | 1 | - | - | - | - | - | 1 | - |
| Sugar Hill | 71 | - | - | - | 2 | - | - | - | - | 2 | 1 |
| Surveyor Springs | 39 | - | 1 | - | 3 | - | - | - | - | 4 | - |
| Tank Creek | 161 | - | 1 | 1 | 2 | - | - | - | - | 4 | - |
| Unknown | n/a | 3 | 9 | 19 | 19 | 13 | 6 | 8 | 2 | 79 | 14 |
| Unknown FGV 1 | n/a | - | - | - | 1 | - | - | - | - | 1 | - |
| Unknown Obsidian 1 | n/a | - | 2 | 3 | 8 | 1 | - | 1 | - | 15 | - |
| Venator FGV | 236 | - | - | - | 1 | - | 1 | - | - | 2 | - |
| Warner Valley FGV | 89 | 1 | - | - | - | - | - | - | - | 1 | - |
| **Total Artifacts** | - | 108 | 319 | 480 | 439 | 149 | 154 | 72 | 40 | 1761 | 207 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Sources** | - | 10 | 15 | 21 | 21 | 11 | 13 | 11 | 5 | 36 | 9 |

Note: Ret.=Retouched, BS/PP/FM=Bordwell Springs/ Pinto Peak/Fox Mountain, GF/LIW/RS=Grasshopper Flats/Lost Iron Well/Red Switchback.

Table 2.7. Source Profile for CCD Locality Clusters.

| | | **Cluster Number** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Toolstone Source** | **Distance to Source (km)**[a] | **C-1** | **C-2** | **C-3** | **C-4** | **C-5** | **C-6** | **C-7** | **C-8** | **C-9** | **C-10** | **C-11** | **CCD (All)** |
| Alturas FGV | 66 | 1 | - | 4 | 1 | 1 | 6 | - | - | - | - | - | 16 |
| Badger Creek | 24 | - | - | 21 | 3 | 3 | 17 | 3 | 1 | - | 1 | - | 84 |
| Beatys Butte | 46 | 4 | - | 25 | 7 | 7 | 34 | 8 | - | 2 | 3 | - | 173 |
| Beatys Butte B | 46 | - | - | - | - | - | 1 | - | - | - | - | - | 6 |
| Blue Spring | 68 | - | - | 1 | 1 | - | 3 | 1 | - | - | - | - | 6 |
| BS/PP/FM | 72 | 1 | - | 2 | - | 1 | 4 | - | - | 1 | 2 | - | 18 |
| Buck Mountain | 62 | 1 | - | 11 | 5 | 2 | 7 | - | - | 1 | 3 | 4 | 48 |
| Buck Spring | 82 | - | - | 1 | - | - | - | - | - | - | - | - | 3 |
| Cowhead Lake | 45 | 4 | - | 14 | 5 | 6 | 15 | 3 | - | 1 | 3 | - | 87 |
| Coyote Springs | 44 | 1 | 1 | 5 | 3 | 2 | 12 | 2 | - | - | 5 | - | 60 |
| Craine Creek | 61 | - | - | - | - | 1 | - | - | - | - | - | - | 4 |
| Coyote Wells | 222 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Double H/Whitehorse | 121 | 1 | - | - | - | 3 | 6 | - | - | - | - | - | 13 |
| Double O | 139 | - | - | 1 | - | - | 1 | - | - | - | - | - | 2 |
| DC/BF | 111 | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| GF/LIW/RS | 191 | - | - | - | - | 1 | 1 | - | - | - | - | - | 2 |
| Glass Buttes | 181 | - | - | 2 | - | - | 4 | - | - | - | - | - | 9 |
| Hawks Valley | 27 | 1 | - | 5 | - | 3 | 13 | - | - | - | 2 | - | 41 |
| Horse Mountain | 137 | - | - | 2 | 2 | - | 3 | - | - | - | - | - | 11 |
| Indian Creeks Butte | 170 | - | - | - | - | 1 | 1 | - | - | - | - | - | 2 |
| Long Valley | 18 | 1 | - | 2 | 1 | 4 | 4 | - | - | 1 | 1 | - | 28 |
| MLGV | <1 | 13 | 4 | 149 | 51 | 53 | 201 | 52 | 7 | 20 | 96 | 3 | 1488 |
| Mosquito Lake | 31 | 2 | - | 12 | 4 | 1 | 17 | 5 | - | 1 | 2 | - | 64 |
| Quartz Mountain | 191 | - | - | - | - | - | 1 | - | - | - | - | - | 2 |
| Rainbow Mines | 68 | - | - | 1 | 1 | - | 2 | - | - | - | - | - | 10 |
| Riley | 165 | - | - | - | - | - | 1 | - | - | - | - | - | 2 |

| | | Cluster Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Toolstone Source** | **Distance to Source (km)**[a] | **C-1** | **C-2** | **C-3** | **C-4** | **C-5** | **C-6** | **C-7** | **C-8** | **C-9** | **C-10** | **C-11** | **CCD (All)** |
| Spodue Mountain | 140 | - | - | - | - | - | - | - | - | - | - | - | 2 |
| Sugar Hill | 71 | 1 | - | 1 | - | - | 3 | - | - | - | - | - | 6 |
| Surveyor Springs | 39 | - | - | 2 | 1 | - | 3 | - | - | - | - | - | 10 |
| Tank Creek | 161 | - | - | - | - | - | 1 | - | - | - | - | - | 4 |
| Unknown | n/a | - | - | 14 | 4 | 4 | 17 | 3 | 2 | 2 | 1 | 1 | 93 |
| Unknown FGV 1 | n/a | - | - | 1 | - | - | 3 | - | - | - | - | - | 5 |
| Unknown Obsidian 1 | n/a | - | - | 3 | - | - | 4 | 2 | 1 | - | - | - | 27 |
| Venator FGV | 236 | - | - | - | - | - | 2 | - | - | - | - | - | 3 |
| Wagon Tire | 152 | - | - | 1 | - | - | - | - | - | - | - | - | 2 |
| Warner Valley FGV | 89 | - | - | - | - | - | 1 | 1 | - | - | - | - | 2 |
| Whitewater Ridge | 250 | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| **Total** | - | 31 | 5 | 282 | 89 | 93 | 388 | 80 | 11 | 29 | 119 | 8 | 2336 |

Note: BS/PP/FM=Bordwell Springs/Pinto Peak/Fox Mountain, ML/GV=Massacre Lake/Guano Valley.

Table 2.8. Local to Non-Local Toolstone Ratios for Diagnostic WST Material at the CCD Locality and Related Sites in the Northwestern Great Basin. Higher Values Indicate Longer Occupations.

| **Site** | **Nearest Toolstone (km)** | **Local Toolstone**[a] | **Nonlocal Toolstone** | **Local to Nonlocal Toolstone Ratio** | **Reference** |
|---|---|---|---|---|---|
| CCD Cluster 1 | <1 | 1 | 13 | 0.08 | This Study |
| CCD Cluster 3 | <1 | 19 | 47 | 0.40 | This Study |
| CCD Cluster 4 | <1 | 15 | 20 | 0.75 | This Study |
| CCD Cluster 5 | <1 | 10 | 14 | 0.71 | This Study |
| CCD Cluster 6 | <1 | 29 | 74 | 0.39 | This Study |
| CCD Cluster 7 | <1 | 15 | 11 | 1.36 | This Study |
| CCD Cluster 10 | <1 | 7 | 7 | 1 | This Study |
| **Catnip Creek Delta Total** | **<1** | **188** | **324** | **0.58** | This Study |
| Paulina Lake (35DS34) | ~4 | 18 | 26 | 0.69 | Connolly and Jenkins (1999) |
| Last Supper Cave[b] | <1 | 22 | 13 | 1.69 | Smith (2008) |
| Hanging Rock Shelter | ~7 | 13 | 17 | 0.76 | Smith et al. (2011) |
| Parman Locality 1 | ~3-5 | 28 | 32 | 0.88 | Smith (2007) |
| Parman Locality 2 | ~3-5 | 13 | 12 | 1.08 | Unpublished |
| Parman Locality 3 | ~3-5 | 11 | 16 | 0.69 | Smith (2007) |
| Parman Locality 4 | ~3-5 | 14 | 13 | 1.08 | Unpublished |
| 35HA840 (Hawksy Walksy) | ~5 | 40 | 35 | 1.14 | Unpublished |
| 35HA2587 (Hawksy Walksy) | ~5 | 16 | 12 | 1.33 | Unpublished |
| 35HA2598 (Hawksy Walksy) | ~5 | 9 | 7 | 1.29 | Unpublished |
| 35HA2599 (Hawksy Walksy) | ~5 | 20 | 224 | 1.11 | Unpublished |

[a] Local toolstone is defined as any toolstone source within a 20-km radius of the site.

[b] In 2008, Smith noted that one WST point was made on Bog Hot Springs obsidian, the location of which was unknown. Since then, researchers have recognized that Bog Hot Springs and Craine Creek, whose location is known, refer to the same geochemical type. As such, the Last Supper Cave data in this table include one additional WST point made on Craine Creek obsidian not included in Smith's (2008) totals

Figure 2.1. Location of the Catnip Creek Delta and related Western Stemmed Tradition sites mentioned in the text

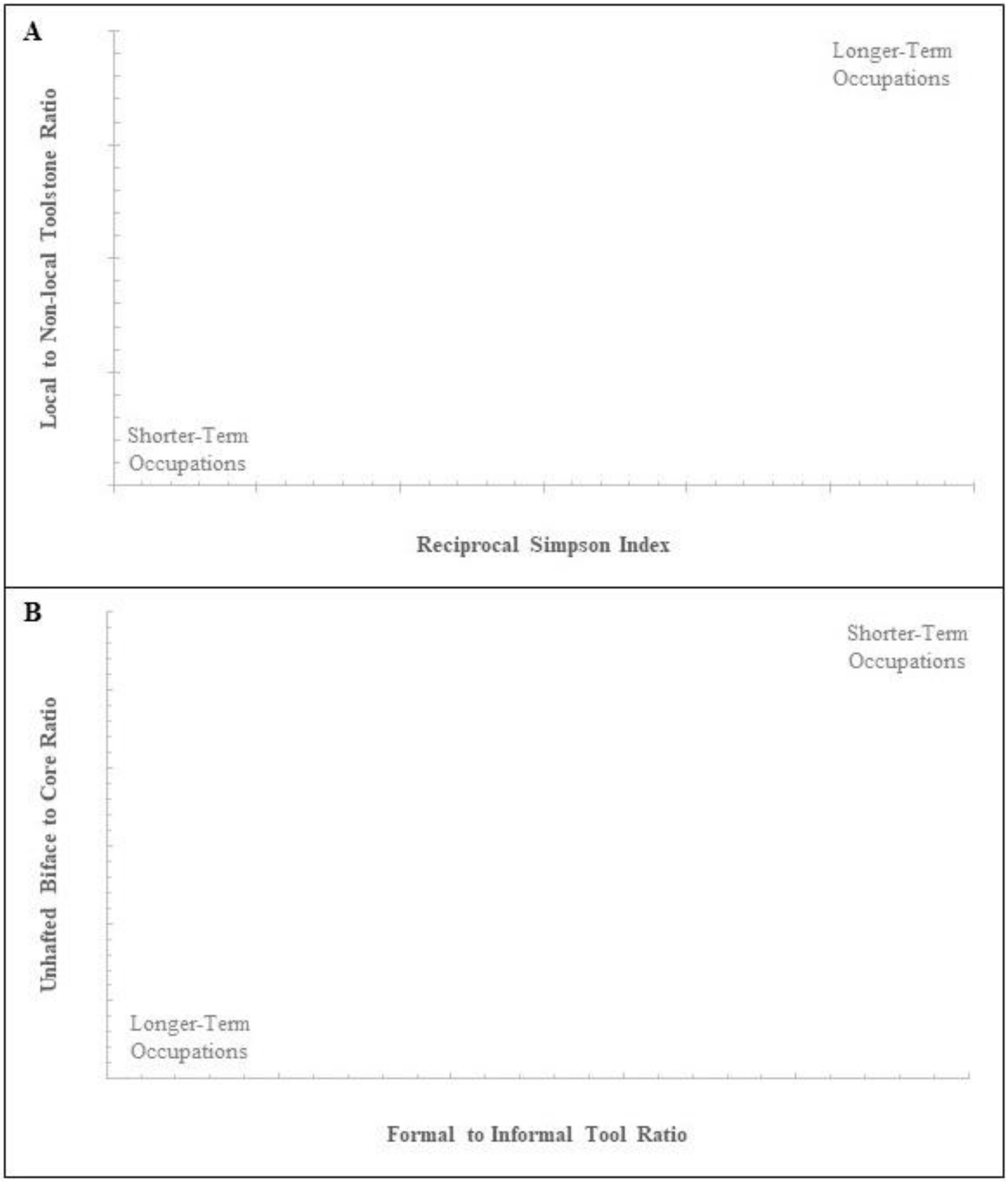

Figure 2.2. (A) longer stays should reflect higher local to non-local toolstone ratios and a more diverse tool assemblage; and (B) longer stays should possess lower formal to informal tool and unhafted biface to core ratios.

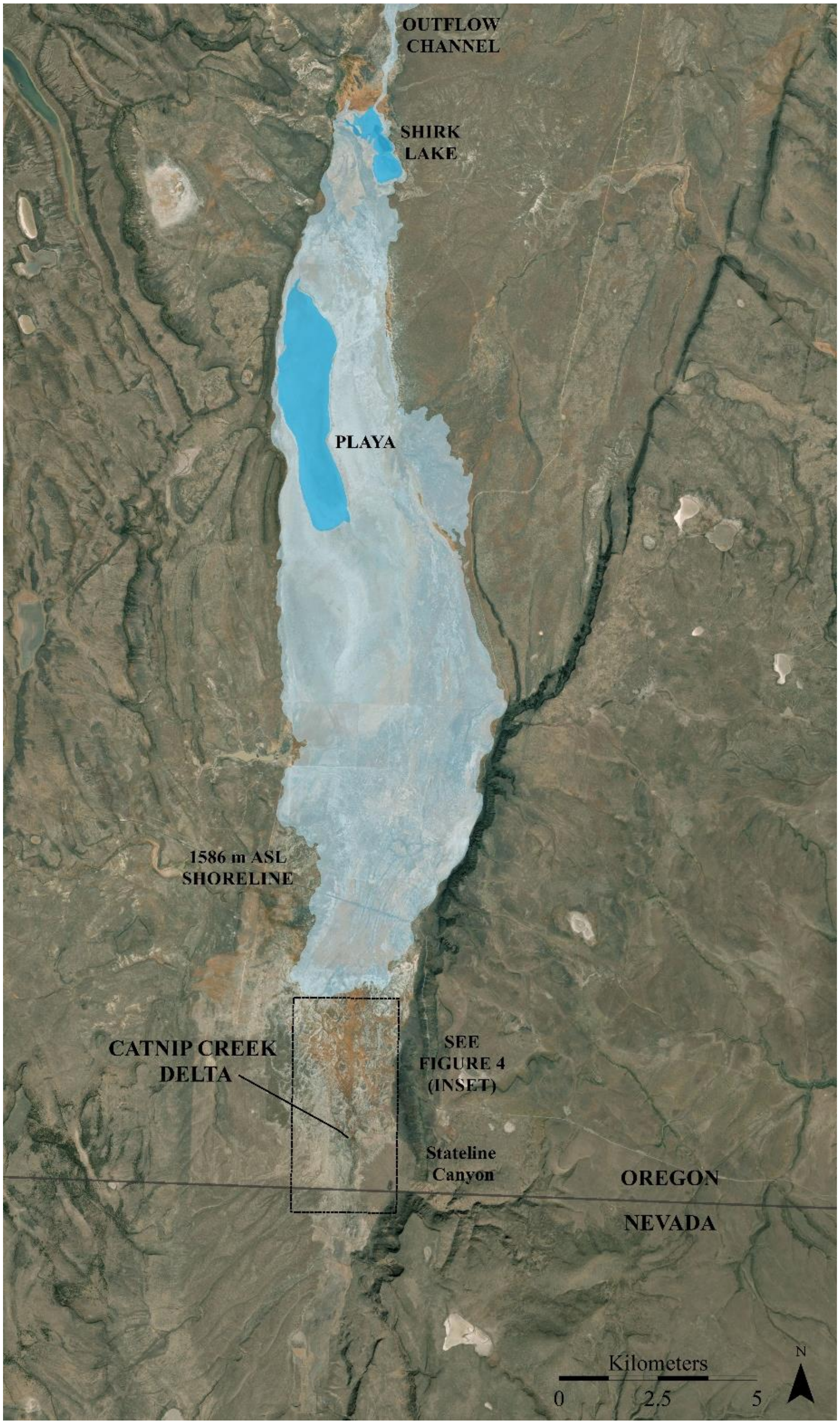

Figure 2.3. Overview of Guano Valley, Oregon.

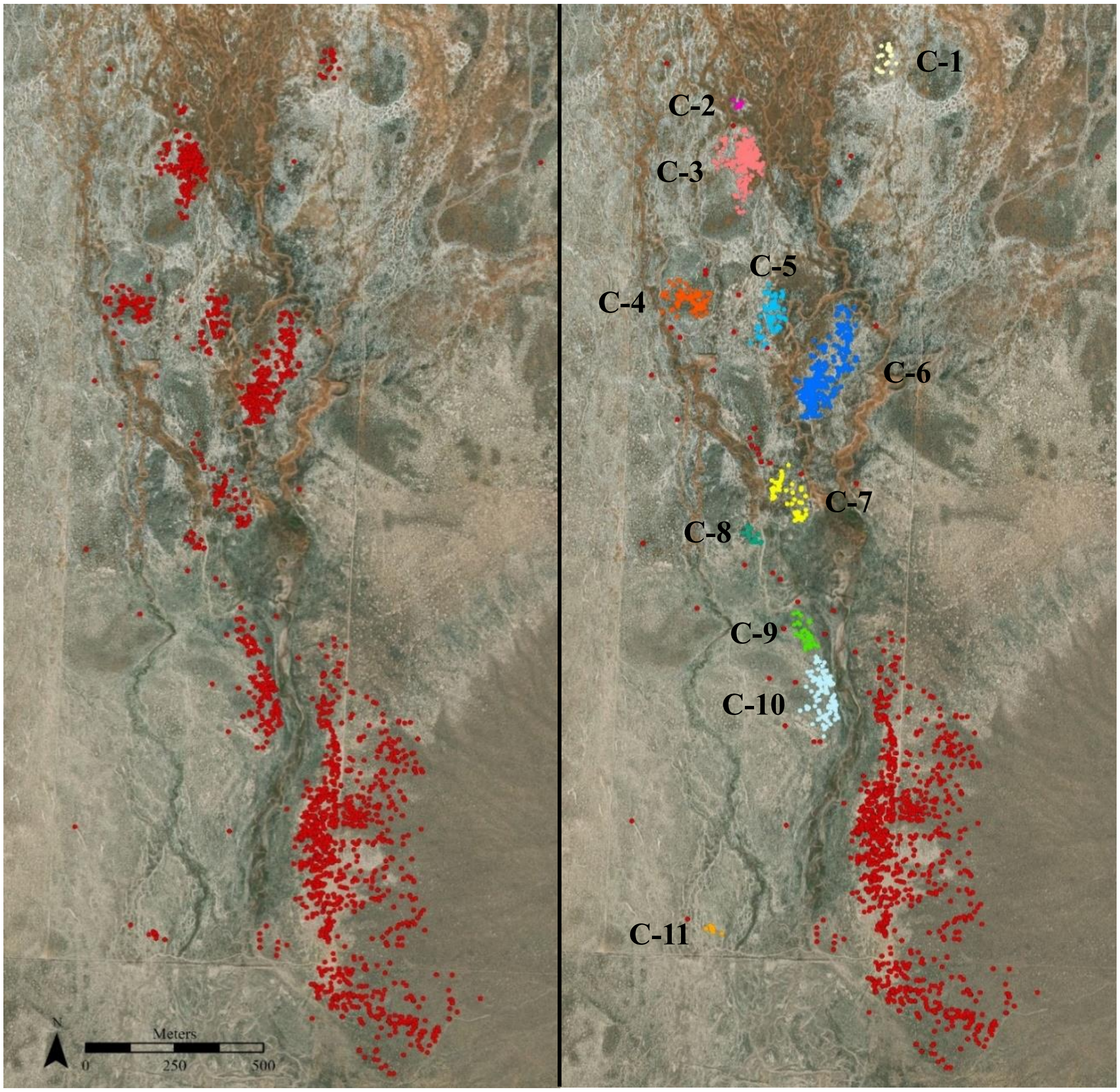

Figure 2.4. (left) the distribution of all artifacts within the CCD; and (right) results of the DBSCAN spatial analysis and locations of clusters mentioned in the text. Red dots (right) represent outliers or areas that could not be adequately analyzed with the DBSCAN tool.

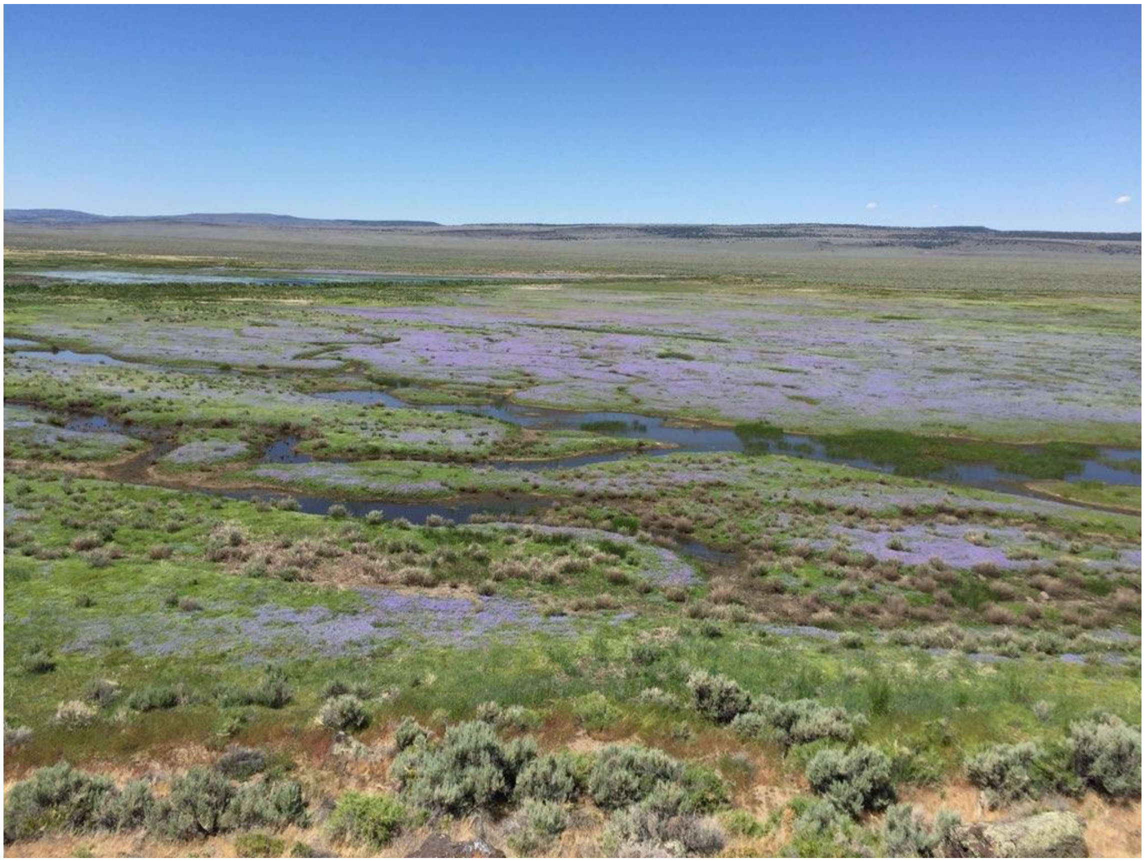

Figure 2.5. Active channels in the Catnip Creek Delta. Channels are located ~1 km south of the major artifact concentrations between two historic-era dams (upper left). While these channels may be recently formed, they provide an idea of what the delta may have looked like during the Early Holocene. Photo looking southwest taken July 2017.

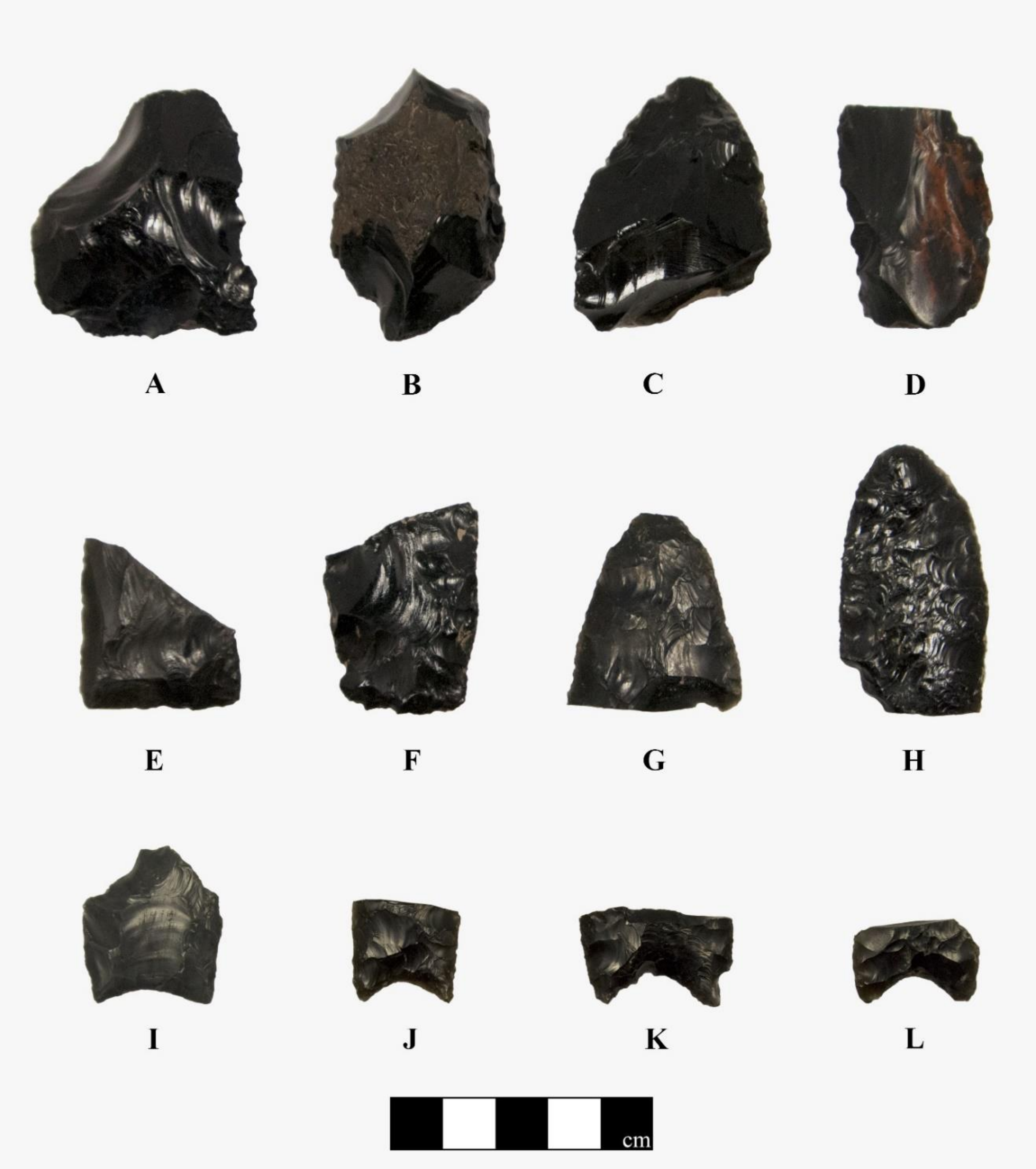

Figure 2.6. Representative sample of bifaces and non-WST Paleoindian artifacts from the CCD Locality: (A-B) early stage bifaces; (C-D) middle stage bifaces; (E-F) late stage bifaces; (G-H) finished bifaces; (I) fluted point; and (J-L) unfluted concave base points.

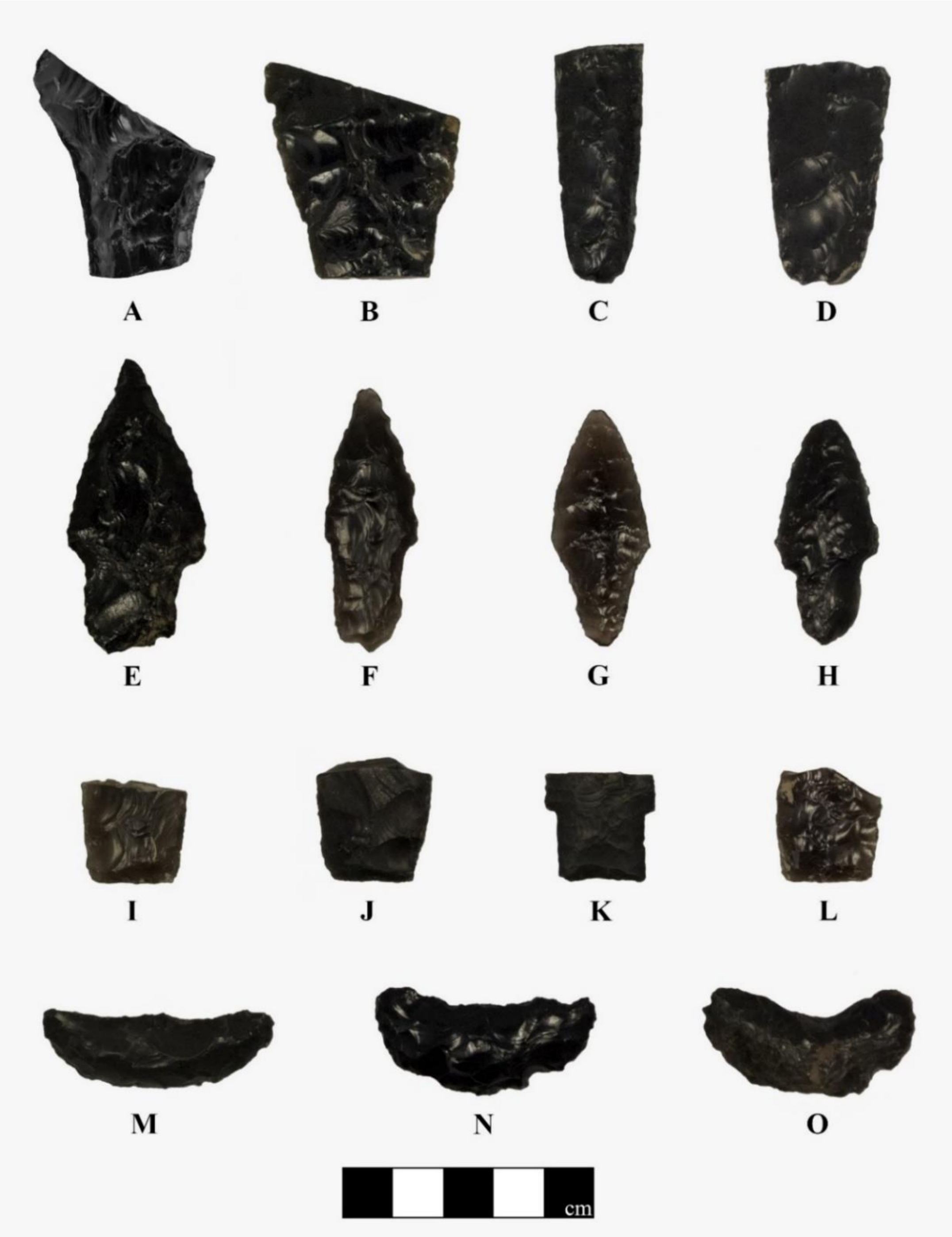

Figure 2.7. Representative sample of WST artifacts from the CCD Locality: (A-B) Cougar Mountain points; (C-D) long-stem fragments; (E-H) Parman points; (I-L) Windust points; and (M-O) crescents.

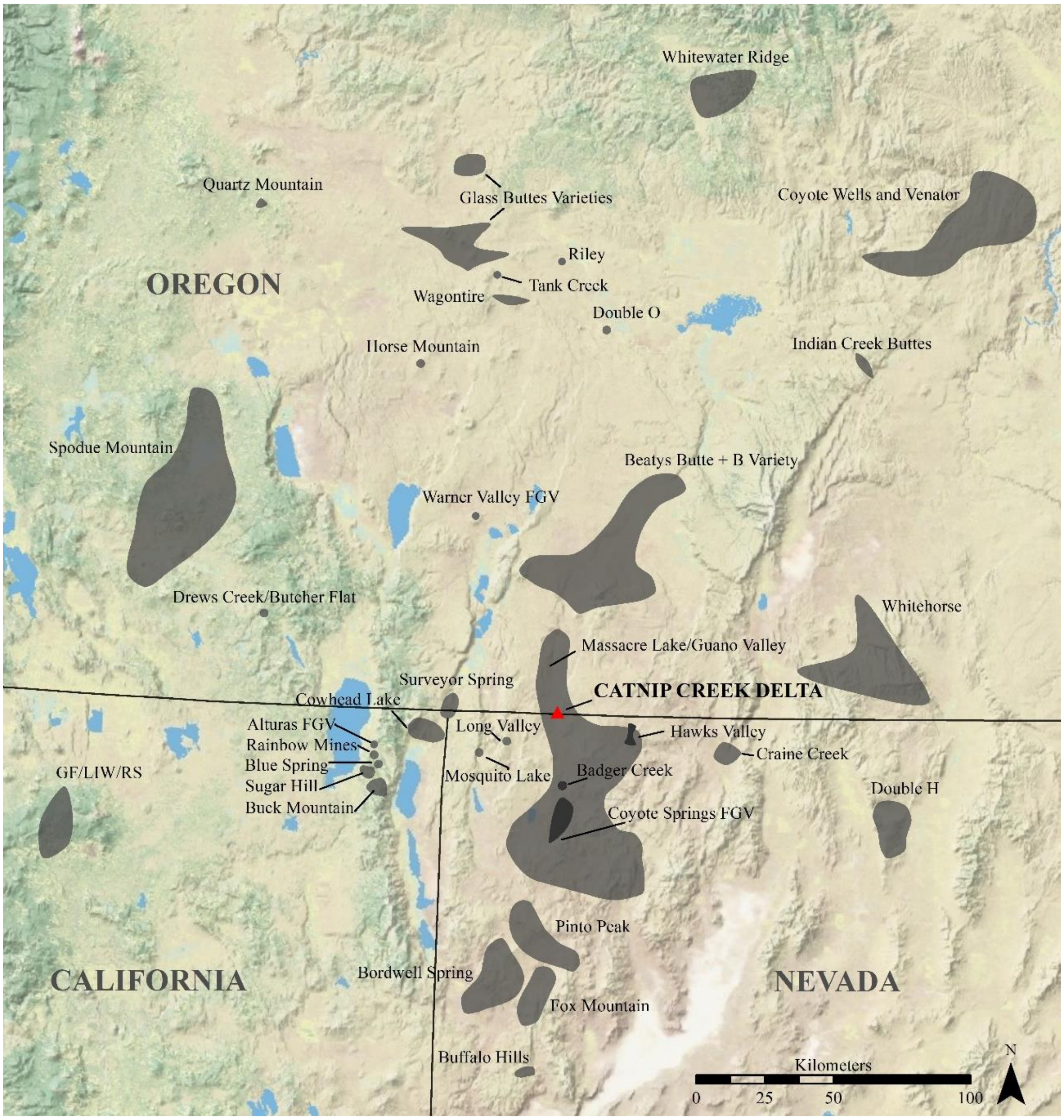

Figure 2.8. Location of the CCD and toolstone sources represented in the CCD Locality assemblage.

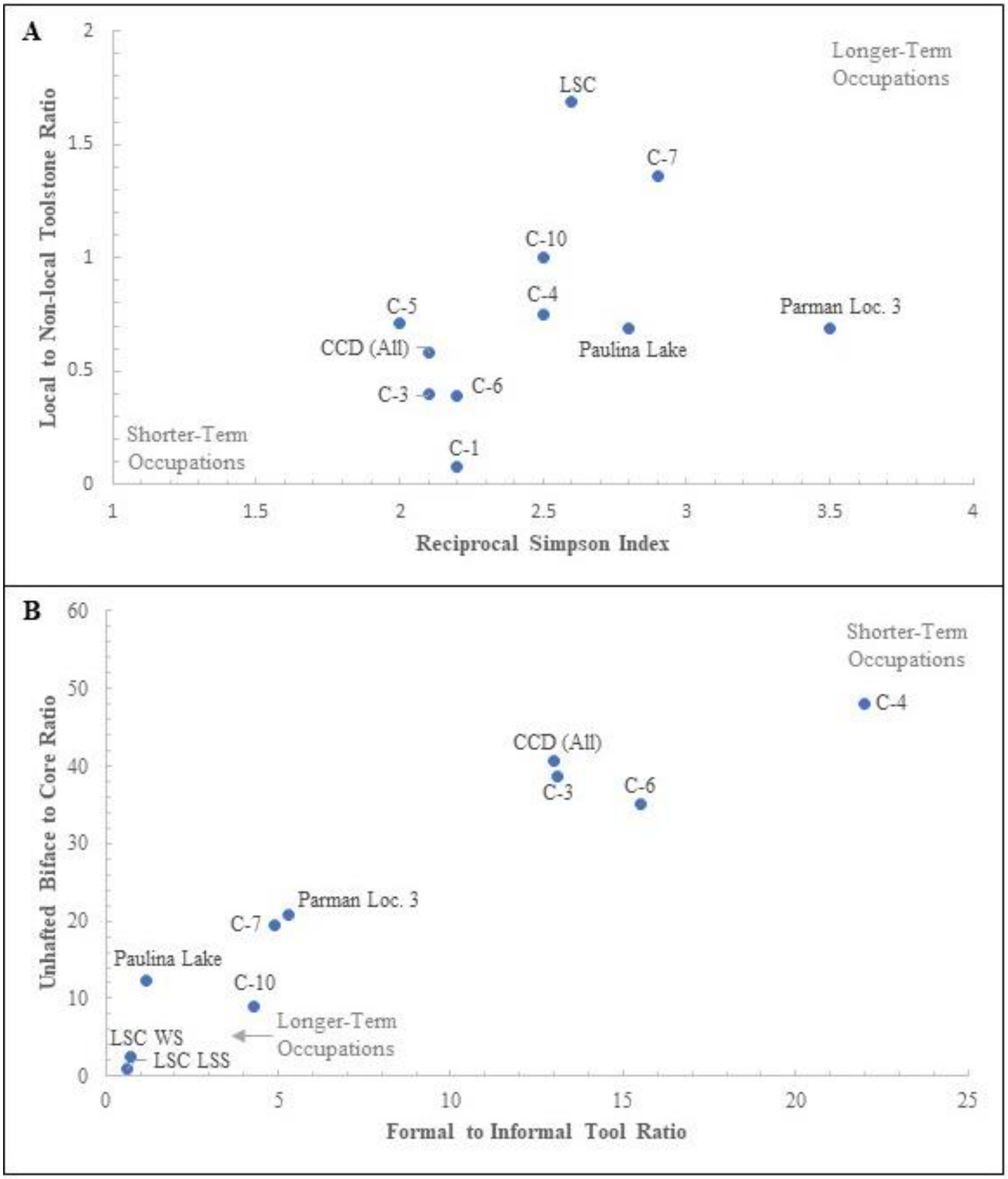

Figure 2.9. (A) comparison of L/NL toolstone ratios and assemblage diversity; and (B) comparison of unhafted biface to core ratios and formal to informal tool ratios between sites discussed in the text. Note: LSC= Last Supper Cave, LSC WW= Last Supper Cave White Stratum, LSC LSS = Last Supper Cave Lower Shell Stratum. LSC WS and LCS LSS are combined in (A) due to data constraints.

# Chapter 3:

# WESTERN STEMMED TRADITION LITHIC PROCUREMENT STRATEGIES AT THE CATNIP CREEK DELTA LOCALITY, GUANO VALLEY, OREGON: A GRAVITY MODEL APPROACH

*Source provenance analyses have long featured prominently in Great Basin Paleoindian archaeology. Such research has primarily focused on reconstructing Paleoindian settlement/subsistence strategies, territoriality, and socioeconomic interactions by sourcing obsidian artifacts from sites and mapping their geographic distributions. While these studies have identified the toolstone sources that early groups used and how they may have conveyed them, few have explicitly addressed why particular materials may have been selected. I present a gravity model that examines the influence of geologic and geographic factors (e.g., toolstone quality and abundance) on Western Stemmed Tradition lithic procurement strategies at the Catnip Creek Delta Locality, Guano Valley, Oregon. My results suggest that groups primarily procured toolstone based on its proximity to wetlands and travel corridors and not sources' overall quality. Western Stemmed Tradition groups may have done this to maximize foraging efficiency within a wetland focused and residentially mobile settlement-subsistence system.*

## Introduction

Lithic source provenance analyses have been an integral part of Great Basin Terminal Pleistocene/Early Holocene (TP/EH) archaeology for the past few decades (e.g., Jamaldin 2018; Jones et al. 2003, 2012; Madsen 2007; Newlander 2012, 2015, 2018; Reaux et al. 2018; Smith 2010). Research has primarily focused on reconstructing mobility, territoriality, and socioeconomic interactions by geochemically characterizing and mapping the geographic distribution of obsidian and fine-grained volcanic (FGV) artifacts. While these studies have effectively demonstrated which toolstone sources early groups used and how people may have conveyed them, few studies have explicitly addressed *why* Paleoindians selected particular raw materials (but see Beck and Jones 1990). In this paper, I present a gravity model that examines the influence of geologic and geographic factors (e.g., toolstone quality and abundance) on Western Stemmed Tradition (WST [13,500-8300 cal BP]) lithic procurement strategies at the Catnip Creek Delta (CCD) Locality in Guano Valley, Oregon. By combining geologic and geographic factors into a single toolstone source attractiveness score, a gravity model predicts which sources should have been used most often. This approach offers a novel way to analyze source provenance data and evaluate current debates about Paleoindian mobility, technological organization, and socioeconomic interactions in the Great Basin.

## Background

While researchers have analyzed and interpreted lithic source provenance data in various ways across the Great Basin (e.g., Hildebrandt et al. 2016; Jamaldin 2016; Newlander 2012; Smith 2006), the lithic conveyance zone (LCZ) concept that Jones et al. (2003, 2012) introduced has dominated such studies. Simply put, LCZs are ellipsoids based on the directions and distances of toolstone movement that encompass the areas within which groups procured and discarded toolstone. In their seminal studies, Jones et al. (2003, 2012) suggested that LCZs represent expansive TP/EH foraging territories through which residentially mobile populations moved.

Since its inception, researchers (e.g., Madsen 2007; Newlander 2012; Smith 2010; Smith and Harvey 2018) have debated Jones et al.'s (2003, 2012) LCZ model and interpretations. Smith (2006) noted that Jones et al.'s (2003) eastern LCZ far exceeded the territorial range of documented foraging societies. Using additional data, Smith (2006, 2010) and Page (2008) modified Jones et al.'s (2003) LCZs in Nevada's High Rock Country and Utah's Bonneville Basin, making them more in line with ethnographic data. Madsen (2007) argued that Jones et al.'s (2003) LCZs might reflect long-distance logistical forays within a more residentially stable system or periodic population aggregations by otherwise dispersed groups. Finally, Newlander (2012, 2015, 2018) challenged Jones et al.'s (2003) LCZs by examining the different conveyance patterns of obsidian, FGV, and cryptocrystalline silicate (CCS) artifacts at TP/EH sites in eastern Nevada. He found that groups conveyed obsidian artifacts greater distances than FGV and CCS artifacts and proposed that the smaller FGV and CCS zones may reflect foraging ranges whereas the larger obsidian zones may reflect trade networks.

Recently, Smith and Harvey (2018) called into question the validity of the LCZ concept, primarily citing issues of equifinality and sampling bias. A primary concern is that most LCZ data are derived from surface sites that likely represent palimpsests spanning centuries or millennia. This issue is compounded by the lack of precise age ranges for many Paleoindian artifacts (Beck and Jones 2014; Goebel and Keene 2014; but see Rosencrance 2019). These issues make it difficult to discern whether a given source profile reflects residential or logistical movements (Jones et al. 2003, 2012; Madsen 2007; Smith 2010), trade/exchange (Newlander 2012, 2015), or some combination of procurement strategies (Hughes 2011). While Smith and Harvey's (2018) criticisms are warranted, source provenance research involving surface assemblages represents one of the only methods to examine TP/EH mobility, technological organization, and socioeconomic interactions in the region. Therefore, we must seek new means of interpreting source provenance data. While the gravity model that I present here is not a panacea to all of the issues that limit the LCZ concept, it does offer a new way to explore WST lifeways in the northwestern Great Basin and other obsidian-rich regions.

### *Gravity Models*

Researchers primarily use gravity models in geography and economics, but some have seen application in archaeology (e.g., Browne and Wilson 2011; Hodder and Orton 1976; Madsen et al. 2015; Wilson 2007). The models are loosely based on Newton's Law of Gravity, which states that the gravitational pull of a celestial body is determined by its overall mass and distance from other celestial bodies (Wilson 2007). Economists commonly employ gravity models to determine where to place a new retail store so that they may outcompete their rivals. The basic premise is that if a new store is large enough, properly located, and offers a high-quality and low-cost product, then consumers will be drawn to it (Wilson 2007). Like consumers today, flintknappers had a number of choices regarding toolstone procurement. In some cases, the most convenient source may have sufficed (e.g., the closest or easiest to obtain). In other cases, specific raw materials may have been required or preferred.

The utility of a gravity model is that it reduces the appeal of a toolstone source into a single source attractiveness score representing gravitational pull based on quantifiable geologic and geographic factors. Attractiveness factors can include raw material abundance, package size, flaking quality, ease of procurement, source accessibility, and distance. By calculating the attractiveness of each raw material, researchers can predict which sources should appear in an assemblage. Importantly, archaeological gravity models generally do not consider the influence of cultural factors (e.g., social organization, territoriality, trade) because they are difficult to quantify and, in some cases, unknowable (Wilson 2007). In essence, the models serve as economic null hypotheses. If predicted source rankings match the toolstone frequencies in an assemblage's source profile, then it suggests that groups behaved in a way consistent with predicted optimality in terms of toolstone procurement. Deviations from the predicted patterns may indicate unrecognized factors that can be further explored. By determining the importance (or lack thereof) of the economic aspect of toolstone procurement, gravity models provide a means to move past some of the limitations of the LCZ concept and generate new discussion about WST lifeways.

### *The Catnip Creek Delta Locality, Guano Valley, Oregon*

Guano Valley is a small basin situated along the Oregon-Nevada border in the northwestern Great Basin (Figure 3.1). The University of Nevada, Reno's Great Basin Paleoindian Research Unit (GBPRU) conducted two years of work in Guano Valley, focusing on a rich WST record associated with a delta system at the valley's southern end referred to as the Catnip Creek Delta (CCD) Locality (Reaux et al. 2018). Within the delta's channel system, we recorded more than 600 WST projectile points and 1970 bifaces, flake tools, and cores, making it one of the densest concentrations of TP/EH material in the region. I have presented results of lithic, source provenance, and spatial analyses of the CCD Locality assemblage elsewhere (see Chapter 2). Based on those investigations, I concluded that the CCD Locality record was a product of repeated, short-term occupations by residentially mobile groups who primarily used the area as a retooling and hunting location.

The CCD Locality is an ideal place to implement a gravity model. The delta contains a source of Massacre Lake/Guano Valley (ML/GV) obsidian along its southern margins and, to a lesser extent, within the channels themselves. The availability of high-quality obsidian within the delta enabled groups to replenish toolkits and discard worn-out artifacts made on non-local raw materials. The northwestern Great Basin is also a toolstone-rich environment with dozens of geochemically-distinct obsidian and FGV types. The 34 unique toolstone types represented in the CCD Locality's TP/EH assemblage reflect this fact (Table 3.1). Given the area's rich lithic landscape, groups could likely have been selective about the raw materials they used because toolstone was widely available.

## Materials and Methods

For this study, I used all geochemically characterized WST points and crescents from the CCD Locality assemblage (see Table 3.1)[1]. While the locations and geochemical profiles of toolstone sources in the northwestern Great Basin are generally well-known, there is little published information about the particular qualities of the different sources of those materials (e.g., cobble size and shape, abundance, presence/absence of inclusions, etc.). To address this shortcoming, I visited 10 obsidian and FGV sources represented in the CCD Locality assemblage (Figure 3.2). I also incorporated the Logo obsidian source although it is not present in the assemblage. Logo obsidian occurs near other utilized sources and provides an opportunity to investigate why groups may have ignored that material. I used previously undocumented primary source locations discovered during my fieldwork for Alturas FGV and Logo obsidian (see Figure 3.2).

I recorded clast size, material quality and abundance, and the environmental and archaeological settings at each source location. Upon arriving at a source, I measured and inspected its extent and characteristics (e.g., cobble density, distribution, and size). At each location, I established a 4-x-4 m unit that contained materials representative of the source. If the source location had variable raw material density, quality, or clast size, I recorded two or more 4-x-4 m grids to capture that variability.

To determine average clast size, I measured the maximum linear dimension of each clast within the 4-x-4 m grid unit. I assessed raw material quality by recording the presence/absence of inclusions in each clast as well as average clast shape (angular/rounded). To assess the presence of inclusions, I analyzed clasts that lacked cortex. I also recorded cortex type (e.g., smooth, crenulated), material color, presence and character of archaeological materials, and the number of pebbles, cobbles, and boulders within each grid unit. Lastly, I measured the abundance of clasts >12 cm at each source (see *scarcity* below). To do this, two crew members recorded the number of clasts >12 cm as they walked in opposite directions away from each grid location for 15 minutes. I combined each crew member’s counts. I did not include material within grid units in these counts. The largest WST point types, Haskett and Cougar Mountain, generally average 9 to 12 cm (Beck and Jones 2009, 2015; Jamaldin 2018); therefore, flintknappers would have needed clasts >12 cm in long axis to manufacture these long-stemmed points (Dan Stueber, personal communication 2019).

## The Gravity Model

To generate predictions about toolstone selection at the CCD Locality, I calculated an *attractiveness score* for each raw material source. This score is based on an attractiveness equation, which considers the costs and benefits of using a given toolstone source. I modified Wilson’s (2007; see also Browne and Wilson 2011) attractiveness equation for Middle Paleolithic toolstone procurement in southern France. Wilson (2007) found that her attractiveness scores were strongly correlated with source use. Browne and Wilson (2011) later applied this equation to a more robust data set and found that it is an effective means of considering the factors that may have influenced toolstone procurement decisions. For this study, I used the following modified version of Wilson's (2007) attractiveness equation[2]:

$$\text{Attractiveness Score} = \frac{(\text{quality})(\text{extent of source})\ (100)}{(\text{source location})\ (\text{extraction cost})} \times \frac{\text{size}}{\text{scarcity}}\ /\ \text{distance}$$

*Quality*. Quality represents the suitability of a clast for flintknapping. I modified Wilson's (2007) equation to assess differences in the quality of obsidian and FGV types. I determined a source's overall quality based on the average shape (i.e., rounded or angular) of the clasts and the presence/absence of inclusions. Angular clasts tend to offer more and better striking platforms and are thus easier to remove flakes for tool production (Dan Stueber, personal communication 2019). Inclusions can reduce an individual's ability to manufacture tools and may cause more frequent catastrophic failures. I quantified inclusions by dividing the number of clasts with inclusions by the total number of clasts per grid unit. Unlike Wilson (2007), I did not use a logarithmic scale to weight the differences in quality between obsidian/FGV sources. While sources that score as *high* are certainly superior to those that score as *very poor*, a rounded clast of high-quality glass in the hands of an expert flintknapper is not vastly inferior to an angular clast of the same material. Thus, I used a linear ordinal scale (*n*=5) to reflect differences in quality between toolstone sources (Table 3.2).

*Size*. Size describes the average maximum dimension of a source's clasts. Sources with larger clasts should have provided greater toolmaking potential. To calculate size values, I used the average length (in cm) of clasts present in each grid unit (see Table 3.2). Because pebbles are too small to produce most WST tools, I did not include them in my size calculations.

*Extent of source*. This represents the areal extent of a toolstone source and is related to the overall abundance of that material and, in turn, the likelihood that individuals will encounter it on the landscape. Some obsidian and FGV sources cover hundreds of square kilometers and clasts within them are various shapes and sizes. In many cases, the areal extent of clasts of suitable size is smaller than the full extent of the source. I calculated the extent of each source using the distribution of cobble-sized or larger clasts (>6.5 cm) based on in-field observations. I modified Wilson's (2007) ordinal size scale (*n*=4) based on average source extents in the region (see Table 3.2).

*Scarcity*. Scarcity influences toolstone procurement costs in this equation and is the inverse of the *extent of source* variable. Scarcity can be used as a proxy for search time. The longer a person searches for toolstone, the less time they have for other tasks (e.g., food acquisition). Because we cannot know an individual's toolstone needs when they visited a source, I calculated scarcity in two ways. First, I calculated it based on the number of cobbles and boulders (>6.5 cm) in each grid unit. I converted the total number of cobbles and boulders to a value on an ordinal scale (*n*=4). I created the scale's divisions by comparing our in-field source density estimations (low, moderate, high, very high) to each source's grid unit cobble counts. For example, moderate density sources contained 25-50 clasts, whereas very high-density sources always contained more than

100 clasts >6.5 cm per 4-x-4 m unit (see Table 3.2). Second, I calculated scarcity by converting the total number of clasts >12 cm recorded during our field visits to a similar ordinal scale. The first measure reflects the abundance of clasts suitable for various types of tools. The second measure reflects the abundance of clasts suitable for the production of long-stemmed WST points.

*Extraction cost*. Extraction cost reflects the effort needed to acquire raw material at the source location: the more energy required to extract toolstone, the less attractive the source is. Because each source in my study features clasts that are widely available on the ground surface, I assigned each source a score of 1. In consideration of future studies that might include different types of sources (e.g., buried materials or veins embedded in bedrock), I provide a hypothetical scoring system to account for such differences (see Table 3.2).

*Source location.* Source location refers to the costs incurred to access each source. I included this measure in lieu of Wilson's (2007) *difficulty of terrain* variable, which consisted of the cost (in kcal/km) of pedestrian travel from the source to the site at which an artifact made on that material was discarded. I did not use that method because it requires the calculation of caloric costs from hypothetical travel routes between the source and discard site. Given the basin and range topography of the region, least cost paths or modified Euclidean paths (see Wilson 2007) are unlikely to provide realistic travel paths and may create unnecessary biases into the equation. Instead, I assigned toolstone sources to one of three physiographic settings: (1) lowlands; (2) uplands; and (3) mountains. Lowland sources occur in low relief areas such as valley bottoms. Upland sources occur in foothills and tablelands. Mountain sources occur in mountain ranges. I used an ordinal scale to reflect the different costs of accessing sources in each setting, assuming most procurement trips would have originated in valley bottoms where WST sites are often found (see Table 3.2).

*Distance.* Distance refers to the Euclidean distance between the toolstone source and the artifact discard site. Although we cannot know where an individual was when they decided to visit a particular source, distance is clearly an important factor in toolstone procurement studies (Jones et al. 2003, 2012; but see Brantingham 2003, 2006). Typically, there should be a distance-decay pattern where artifacts made on exotic materials are less common than artifacts made on local materials (*sensu* Renfrew 1977). In a logistical procurement system, nearby sources should also be common because they would have been less costly to procure than distant sources. In a residential procurement system, nearby sources should be common because they may have been the last places visited before people occupied a site, whereas distant sources should be rare because tools made on those materials remained in systemic contexts longer and thus had a higher chance of being discarded as groups moved across the landscape. While WST groups almost certainly traded items like marine shell beads across substantial distances in some cases (Fitzgerald et al. 2005; Smith et al. 2016), I do not expect trade to have played a major role in toolstone procurement in the northwestern Great Basin given its rich lithic landscape. Lastly, distance is site specific and will change depending on the assemblage one is studying, but the other variables I outlined above will not. Thus, by removing distance from the equation, I can obtain a baseline score for each source that can be applied to other assemblages. I calculated the final attractiveness scores by dividing the baseline score by the distance variable.

### *Assumptions, Predictions, and Expectations*

This gravity model carries a number of assumptions. First, it assumes that when people were faced with a choice of toolstone sources to exploit they were always drawn to the most attractive one. Second, like most optimal foraging theory models, it assumes that individuals had complete knowledge of the landscape and attractiveness of all toolstone sources (Wilson 2007). Third, it assumes that the distribution and quality of toolstone sources are similar today to what they were in the past and that human activity (e.g., quarrying/toolstone use) did not affect the attractiveness of a source. Finally, it assumes that groups acquired toolstone near the grid units on which many of the variables in the model are based.

Gravity models allow researchers to predict which toolstone sources people should have used if behaving optimally, in essence serving as null hypotheses. Within the context of the northwestern Great Basin and the CCD Locality specifically, the model that I developed predicts that: (1) the most attractive sources (i.e., those with abundant, high quality, large, and easily accessible clasts) will be well-represented; (2) sources with low attractiveness values (i.e., those that are costly to access, scarce, small in size, and/or of poor quality) should be absent or uncommon; and (3) cultural factors for which the model does not account (e.g., patterned movements across the landscape, cultural preferences, etc.) may cause some deviations between predicted and actual source use frequencies.

# Results

## *Toolstone Source Attractiveness Scores*

Table 3.3 presents the data I used to calculate attractiveness scores for the toolstone sources. Table 3.4 presents the results of the attractiveness equations. Columns 2 and 3 of Table 3.4 display baseline scores (distance variable not included) for each source using both scarcity measurements. Baseline attractiveness scores range between 7500 and 175. Coyote Springs FGV has an exceptionally high score (7500) because it is a geographically extensive source dominated by abundant, high-quality, large clasts. Conversely, despite also being high-quality material, Cowhead Lake obsidian has a lower score (1500) because it is a localized, low to moderate-density source characterized by small clasts. To see how each variable affected baseline scores, I removed a variable and reran the equation for each source. I did this for every variable. A combination of size, scarcity, and areal extent are primarily responsible for the wide range of scores. Toolstone quality minimally affects attractiveness scores because most sources possess good to high-quality material. While removing variables from the equation created variations in baseline scores, the variations were often minimal and rarely changed a source's attractiveness ranking (see below).

Columns 4 and 5 of Table 3.4 present source scores specific to the CCD Locality (i.e., baseline scores divided by distance to the CCD). These scores range between 170 and 1. Despite their distance from the CCD Locality, Coyote Springs FGV and Beatys Butte obsidian remain two of the most attractive sources. Long Valley and Hawks Valley obsidian were the only sources to become considerably more attractive (relative to their base scores) when distance is incorporated. The differences in both baseline and final scores using the two different scarcity measurements (frequency of clasts >6.5 cm and >12 cm) were minimal (only Hawks Valley and Long Valley sources improved in rank), suggesting that the abundance of large clasts may not have been a major factor conditioning toolstone procurement decisions at the CCD Locality.

### *Predicted Ranks vs. Actual Source Abundances*

Table 3.5 presents the model's predicted source rankings and the actual source frequencies in the CCD Locality assemblage. I based predicted source rankings on the final attractiveness scores in Table 3.4 (columns 2 and 3). If groups procured toolstone optimally at the CCD Locality, then the predicted ranks should correlate with the assemblage's actual source frequencies (Column 1). Beatys Butte obsidian, the most common non-local source, is commonly the highest ranked obsidian source. Additionally, Logo obsidian, which is absent in the assemblage, is consistently the lowest-ranked source by a large margin. However, the remaining predicted ranks do not correspond closely to the actual source frequencies. Two of the highest-ranked sources, Coyote Springs FGV and Hawks Valley obsidian, are far less common in the CCD Locality assemblage than predicted. Conversely, while Cowhead Lake, Badger Creek and Mosquito Lake obsidian are three of the lowest ranked sources, they are actually the second, third, and fourth most common sources in the assemblage. Removing variables from the equation did not produce predicted rankings more in line with the CCD Locality source frequencies.

## Discussion

The frequencies of Beatys Butte (common) and Logo (uncommon) obsidian and their respective rankings (high and low) correspond to the model's predictions; however, in most other cases the predicted source ranks do not align well with actual source frequencies. As I outlined above, deviations between predicted ranks and actual source frequencies may occur because gravity models do not account for cultural variables (e.g., territoriality, settlement-subsistence strategies). The high number of deviations in my model suggests that cultural and/or other economic factors beyond overall source quality (e.g., resource distribution, mobility) shaped lithic procurement decisions at the CCD Locality. The model's predictions and my in-field observations provide a means of exploring these deviations and the specific factors that may have caused them. For example, Cowhead Lake, Mosquito Lake, and Long Valley obsidian are well-represented in the assemblage but among the lowest ranked sources. One possible explanation for this deviation is that those sources were among the final ones visited before groups arrived at the CCD Locality from the south-southwest. It is also possible that toolstone quality was not as important in the toolstone-rich northwestern Great Basin because tools made of lower-quality material could be easily replaced with those made of higher-quality material.

Interestingly, those sources trend opposite of a distance decay pattern: the most distant source (Cowhead Lake) is actually the most common in my sample. The model provides a possible explanation for this. When using baseline scores (i.e., excluding distance), Cowhead Lake obsidian is considerably more attractive than Mosquito Lake and Long Valley obsidian (see Figure 3.4). It is possible that groups in route to the CCD Locality replenished their toolkits with higher-quality Cowhead Lake obsidian, knowing that the next sources they encountered were of lower quality. However, despite being more distant and of lower quality, Mosquito Lake is more common than Long Valley obsidian. One explanation is that Mosquito Lake obsidian is located just ~500 m from a relict wetland whereas Long Valley obsidian is located ~5 km away from the closest relict wetland. Thus, groups may have used Mosquito Lake obsidian more frequently due to its proximity to a wetland. We observed abundant lithic detritus including WST point fragments around Mosquito Lake but very little near Long Valley, which provides some support for this idea.

The Surveyor Springs source also supports the idea that source location was an important variable. Surveyor Springs is a fairly widespread source that contains large, high-quality clasts; however, it is situated in rugged uplands. While it is located just north of the Mosquito Lake and Cowhead Lake sources and roughly the same distance from the CCD Locality, it comprises just 1 percent of the sourced artifacts. Coyote Springs FGV is a similar case. It is consistently the highest-ranked source in the model but despite being of high quality and relatively close to the CCD Locality it is not as abundant as the model predicted (see Figure 3.4). Like Surveyor Spring obsidian, Coyote Springs FGV is located in rugged uplands far from pluvial lake basins. The lower-than-expected abundances of both Surveyor Springs obsidian and Coyote Springs FGV suggest that proximity to wetlands, not source quality alone, may have influenced toolstone procurement. Having said that, these sources are surrounded by other sources. Their limited use could also be related to a lack of need for additional toolstone (i.e., toolkits were full and easily maintained). The proximity of toolstone sources to one another may be an important factor worth exploring in future studies (*sensu* Ingbar 1994).

The predicted ranks for the Warner Mountains sources (Buck Mountain, Sugar Hill, and Logo obsidian, Alturas FGV) do not align with their actual frequencies. These obsidian and FGV sources occur within 25 km of each other in the Warner Mountains. With the exception of Logo obsidian, each material type is represented in the CCD Locality assemblage. I anticipated that differences in source frequencies would correlate with attractiveness scores but this was not the case, with exception of Logo obsidian. Logo obsidian possessed the lowest attractiveness score due to its limited areal extent and poor-quality material (see Figure 3.3). In my field visits, I noted abundant clasts of Logo obsidian in road cuts and gravel quarries, suggesting that material was not common in surface exposures. This fact may have contributed to its infrequent use by WST groups (i.e., cost of extraction).

The other more well-represented Warner Mountain sources have similar high attractiveness scores; however, Buck Mountain—the most well-represented of those sources—has the lowest attractiveness score. Several factors may have contributed to its frequent use. First, the Buck Mountain source possesses the greatest areal extent of the Warner Mountain sources; therefore, groups would have had a higher chance of encountering it, all other factors being equal. Second, undocumented secondary deposits may alter the areal extent of the Warner Mountain sources, including Buck Mountain, which would impact their attractiveness scores. In our field visits, we noted secondary deposits of obsidian and FGV along the eastern shore of Goose Lake at the base of the Warner Mountains. We collected and characterized a sample of those cobbles. With the exception of Logo obsidian, we identified all of the Warner Mountain obsidian/FGV sources with Buck Mountain obsidian being the most common characterized type. As such, its widespread availability in secondary deposits (Young 2002) may have contributed to its abundance in the CCD Locality assemblage. Finally, a preference for colored obsidian may have also played a role. To my knowledge, Buck Mountain obsidian is the only Warner Mountain source that features mahogany and banded material (see Figure 3.3). Among the WST points from the CCD Locality made of Buck Mountain obsidian, mahogany is the most common color. Ethnographically, the Surprise Valley Paiute, whose territory included the Warner Mountains, preferred red obsidian for arrows because they perceived it to be more durable than black obsidian and because it “cost like buckskin” due to its rarity (Kelly 1932:144). Earlier groups may have shared a similar preference for colored obsidian.

Finally, despite being the lowest-ranked material type present in the assemblage Badger Creek obsidian is fairly abundant. This source occurs in small drainages near Badger Creek, which drains into southern Guano Valley. During fieldwork, we recorded WST artifacts, some made of Badger Creek obsidian, in those drainages. The presence of those artifacts suggests that groups used the canyons to access the volcanic tablelands to the south, where other substantial WST sites including the Parman Localities (Smith

2006), Last Supper Cave (Felling 2015), and Hanging Rock Shelter (Layton 1970) are located.

### *Implications for WST Settlement-subsistence and Toolstone Procurement*

Although this study focuses on a single site, it provides possible broader insights into WST settlement-subsistence and toolstone procurement strategies in the northwestern Great Basin. Assuming that the model effectively quantifies a source's overall quality, these results indicate that source quality alone did not dictate WST toolstone procurement strategies. Instead, my findings suggest that WST groups may have primarily used sources, regardless of quality, that could be easily accessed while carrying out other foraging activities near wetland base camps (see Chapter 2) or during residential movements between wetlands. This is exemplified by the abundant use of the Cowhead Lake and Mosquito Lake sources. Despite being of moderate to low quality relative to other sources, groups likely frequently exploited them due to their proximity to nearby wetlands. Likewise, the frequent use of the Badger Creek obsidian, an additional low-ranking source, was likely due to its accessibility along a likely travel route that leads into the CCD Locality from the south.

The CCD Locality, the Parman Localities (Smith 2006), and Hawksy Walksy Valley (Christian 1997) represent three of the densest concentrations of WST material in the region. Like Cowhead and Mosquito Lake, each of these locations possess locally available toolstone immediately adjacent to wetlands and WST sites. This suggests that WST groups in the region may have preferred, when possible, to situate their basecamps in locations that provided immediate access to both toolstone and wetland resources. Such a strategy would negate some of the costs of toolstone procurement by allowing it to be embedded in other daily foraging activities or even be delegated to children or elders who would not have to travel far from camp. It also supports Elston et al.'s (2014) hypothesis that groups situated their camps in locations that would facilitate both men's (e.g., large game hunting, toolstone procurement) and women's (e.g., large/small game hunting, gathering wetland resources) foraging goals. Lastly, the limited use of high-ranked sources located far from wetlands suggests that long-distance logistical forays were not common or that toolstone procurement was not regularly embedded within them. The results presented here and in Chapter 2 support the former.

In sum, my results tentatively suggest that groups at the CCD Locality embedded toolstone procurement in daily activities and camp movements likely to maximize foraging efficiency within a wetland focused and residentially mobile settlement-subsistence strategy (*sensu* Jones et al. 2003, 2012; Smith 2010). Ultimately, this model needs to be tested with additional assemblages to determine if these patterns hold up at other sites in the northwestern Great Basin. Nevertheless, this study demonstrates the utility of the gravity model approach and, with additional studies, we can begin reassessing the interpretations generated by the LCZ method.

## Conclusion

Source provenance studies are a vital component of archaeological research in the Great Basin. While methods such as reconstructing LCZs are still useful, identifying the types of behavior that produced them remains difficult (Smith and Harvey 2018). The value of the gravity model approach is that it provides a means of exploring why groups used particular sources but ignored others. In this study, the model predicted that Beatys Butte, the highest ranked obsidian source, would be a dominant toolstone type in the CCD Locality WST assemblage. The model also predicted that Logo obsidian, the lowest ranked source, would be scarce or absent.

While the model predicted the abundances of the highest and lowest-ranked sources, it failed to predict the frequencies of most other sources in the CCD Locality assemblage. By revealing deviations from its predictions, the model serves as a starting point to explore why a site's source profile does not conform to basic economic predictions. Deviations may be a function of various factors. For instance, in this study I put forth possible explanations for the deviations in distance-decay patterning (overall quality, proximity to wetlands), why Buck Mountain obsidian was preferred over other nearby sources (its areal extent, color, or abundant secondary deposits), and why the low-ranked Badger Creek source was common (it may have lay along a travel corridor). I concluded that my results suggest that WST groups at the CCD Locality did not generally procure toolstone based on a source's overall quality. Instead, proximity to wetlands and travel corridors was a driving factor in procurement decisions. This practice was likely used to maximize the efficiency of a residentially mobile wetland centric settlement-subsistence strategy. Finally, for researchers interested in this approach, attractiveness equations and scoring systems can be modified and improved upon to fit any other time periods, environments, or raw material types. While issues of equifinality are unavoidable, gravity models offer a deeper understanding of source profiles and new ways to explore mobility, settlement patterning, technological organization, and socioeconomic interactions in the Great Basin and beyond.

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## Notes

1. GBPRU staff characterized most of the CCD Locality material using our Olympus Delta DP-6000 portable X-ray fluorescence device. We sent artifacts that did not match our comparative collection to the Northwest Research Obsidian Studies Laboratory (NWROSL) for further characterization. The Delta model uses a 40 kV Rhodium (Rh) anode X-Ray tube and Olympus Innov-X Systems software. We employed the fundamental parameters calibration provided by the Innov-X software and ran our device using the two-beam (40 and 10 kV) GeoChem mode at 60 seconds per beam. To build our comparative collection, we initially characterized nearly 1000 previously sourced artifacts analyzed by the NWROSL between 2004 and 2013. Over 60 geochemically distinct obsidian/ FGV types from the northwestern Great Basin are represented in that sample. Additionally, over the last five years we visited known obsidian and FGV source locations around the northwestern Great Basin to collect geologic samples to build a more robust comparative collection. Our comparative collection currently contains over 90 geochemically distinct obsidian and FGV types from our study area. To make source assignments, we initially analyzed ratios (in parts per million) of the Mid-Z elements strontium (Sr), zirconium (Zr), niobium (Nb), yttrium (Y), and rubidium (Rb) using bivariate scatterplots with R software. With the growth of our comparative collection, we have transitioned to statistically assigning all sources using discriminant function analysis in the FORDISC program (Pilloud et al. 2017). To assess the accuracy of our in-house assignments using these methods, we submitted 43 previously uncharacterized artifacts from the Parman Localities (Smith 2007) to the NWROSL for geochemical

characterization. Our source assignments of those artifacts matched the NWROSL's source assignments perfectly, indicating that our results are accurate.

2. The 100 is incorporated into the attractiveness equation to ensure the results are whole numbers and to remove unnecessary decimal points (Wilson 2007). Source benefits are in the numerator position whereas the costs of procuring a source is in the denominator position.

Table 3.1. Source Profile for Diagnostic Paleoindian Artifacts in the CCD Locality.

| | | Projectile Point Type | | | | |
|---|---|---|---|---|---|---|
| **Toolstone Source** | **Distance to Source (km)[a]** | WST | Crescent | CCB | Fluted | **Total** |
| Alturas FGV | 72 | 6 | - | - | - | 6 |
| Badger Creek | 25 | 31 | 1 | 3 | - | 35 |
| Beatys Butte | 46 | 82 | 2 | - | - | 84 |
| Beatys Butte B | 46 | 2 | 1 | 1 | 1 | 5 |
| Blue Spring | 68 | 4 | - | - | - | 4 |
| BS/PP/FM[b] | 72 | 7 | - | - | - | 7 |
| Buck Mountain | 62 | 25 | 3 | 1 | - | 29 |
| Cowhead Lake | 46 | 44 | - | - | - | 44 |
| Coyote Spring | 44 | 13 | 1 | - | - | 14 |
| Coyote Wells | 222 | 1 | - | - | - | 1 |
| Double H/Whitehorse[b] | 121 | 9 | - | - | - | 9 |
| Double O | 139 | 2 | - | - | - | 2 |
| Drews Creek/Butcher Flat[b] | 111 | 1 | - | - | - | 1 |
| GF/LIW/RS[b] | 191 | 2 | - | - | - | 2 |
| Glass Buttes | 181 | 5 | - | - | - | 5 |
| Hawks Valley | 27 | 18 | - | - | - | 18 |
| Horse Mountain | 137 | 7 | - | - | - | 7 |
| Indian Creeks Butte | 170 | 1 | - | - | - | 1 |
| Long Valley | 18 | 10 | 2 | 1 | - | 13 |
| Massacre Lake/Guano Valley[b] | <1 | 188 | 10 | 8 | - | 206 |
| Mosquito Lake | 31 | 29 | - | - | - | 29 |
| Quartz Mountain | 191 | 1 | - | - | - | 1 |
| Rainbow Mines | 71 | 5 | - | - | - | 5 |
| Riley | 165 | 2 | - | - | - | 2 |
| Spodue Mountain | 140 | 1 | - | - | - | 1 |
| Sugar Hill | 71 | 4 | - | - | - | 4 |
| Surveyor Springs | 39 | 6 | - | - | - | 6 |
| Tank Creek | 161 | 1 | - | - | - | 1 |
| Unknown | n/a | 15 | - | - | - | 15 |
| Unknown FGV 1[c] | n/a | 4 | - | - | - | 4 |
| Unknown Obsidian 1[c] | n/a | 11 | 1 | - | - | 12 |
| Venator FGV | 236 | 1 | - | - | - | 1 |
| Wagon Tire | 152 | 2 | - | - | - | 2 |
| Warner Valley FGV | 89 | 1 | - | - | - | 1 |
| Whitewater Ridge | 250 | 1 | - | - | - | 1 |
| **Total Artifacts** | **-** | **542** | **21** | **14** | **1** | **578** |

Note: CCB=concave base, BS/PP/FM=Bordwell Springs/Pinto Peak/Fox Mountain, GF/LIW/RS=Grasshopper Flats/Lost Iron Well/Red Switchback.
[a] Euclidean distances measured from CCD to nearest known source for each raw material type.
[b] Sources with multiple names and/or locations but are geochemically identical.
[c] Geochemically distinct sources with unknown geographic locations.

Table 3.2. Toolstone Source Assessment Guide.

| Variable | Definition | Scoring Criteria | Score |
|---|---|---|---|
| Quality | The suitability of a toolstone source for tool production | Very poor (angular/rounded shape, many inclusions [>50%]) | 1 |
| | | Poor (rounded shape, some inclusions [<50%]) | 2 |
| | | Fair (angular shape, some inclusions [<50%]) | 3 |
| | | Good (rounded shape, no inclusions) | 4 |
| | | High (angular shape, no inclusions) | 5 |
| Size | The average length of a source's raw material packages in centimeters | Average maximum linear dimension for cobbles within 4x4 m grid | - |
| Extent of Source | The amount of ground that the toolstone source covers | Small (< 5 km$^2$ in diameter) | 1 |
| | | Medium (5-20 km$^2$ in diameter) | 2 |
| | | Large (20-50 km$^2$ in diameter) | 3 |
| | | Extensive (>50 km$^2$ in diameter) | 4 |
| Scarcity of Material >6.5 cm | The inverse of the extent of source measurement. Directly refers to the time spent searching for a piece of suitable raw material | Very abundant (>100 cobbles >6.5 cm in 4x4m grid) | 1 |
| | | Abundant (50-100 cobbles >6.5 cm in 4x4m grid) | 2 |
| | | Medium (25-50 cobbles >6.5 cm in 4x4m grid) | 3 |
| | | Scarce (<25 cobbles >6.5 cm in 4x4m grid) | 4 |
| Scarcity of Material >12 cm | The inverse of the extent of source measurement. Directly refers to the time spent searching for a package large enough to make the entire suite of WST technology | Very abundant (>100 cobbles >12 cm recorded in 15-minute search) | 1 |
| | | Abundant (50-100 cobbles >12 cm recorded in 15-minute search) | 2 |
| | | Medium (25-50 cobbles >12 cm recorded in 15-minute search) | 3 |
| | | Scarce (<25 cobbles >12 cm recorded in 15-minute search) | 4 |
| Extraction Cost | The effort required to obtain suitable pieces of raw material | Low effort extraction (surface collection of material) | 1 |
| | | Medium effort extraction (digging shallow pits) | 2 |
| | | High effort extraction (digging deep pits or mining from rock faces) | 3 |
| Source Location | The effort required to traverse the terrain the source is located in | Lowlands (limited elevation gain) | 1 |
| | | Uplands (moderate elevation gain) | 2 |
| | | Mountains (high elevation gain) | 3 |

Table 3.3. Toolstone Source Recording Results.

| Source | Quality | Extent | Source Location | Avg. Size (cm) | Packages >6.5 cm in 4x4m grid | Scarcity (>6.5 cm) | Large Package Count (>12 cm) | Scarcity (>12 cm) | Distance from CCD | WST Tool Count |
|---|---|---|---|---|---|---|---|---|---|---|
| Hawks Valley | 5 | 2 | 1 | 8.0 | 50 | 3 | 30 | 3 | 27 | 18 |
| Sugar Hill | 5 | 2 | 4 | 8.5 | 263 | 1 | 93 | 2 | 75 | 4 |
| Badger Creek | 5 | 1 | 2 | 6.5 | 86 | 2 | 11 | 4 | 25 | 32 |
| Coyote Springs | 5 | 3 | 2 | 15.0 | 160 | 1 | 1177 | 1 | 44 | 14 |
| Mosquito Lake | 2 | 1 | 1 | 7.0 | 46 | 3 | 1 | 4 | 31 | 29 |
| Cowhead Lake | 5 | 1 | 2 | 6.5 | 102 | 1 | 25 | 3 | 46 | 44 |
| Alturas | 5 | 1 | 2 | 14.0 | 208 | 1 | 146 | 1 | 72 | 6 |
| Beatys Butte | 5 | 4 | 2 | 7.5 | 78 | 2 | 134 | 1 | 54 | 84 |
| Long Valley | 4 | 1 | 1 | 6.5 | 47 | 3 | 11 | 4 | 18 | 12 |
| Buck Mountain | 5 | 3 | 4 | 10.0 | 69 | 2 | 45 | 2 | 71 | 28 |
| Logo | 1 | 1 | 2 | 7.0 | 21 | 4 | 21 | 4 | 71 | 0 |

Table 3.4. Attractiveness Score Results. Final Scores Represent the Baseline Score Divided by the Distance from the Source to the CCD Locality.

| Source | Baseline Score (Scarcity: >6.5 cm) | Baseline Score (Scarcity: >12 cm) | Distance to CCD Locality (km) | Final Score (Scarcity: >6.5 cm) | Final Score Scarcity: >12 cm) |
|---|---|---|---|---|---|
| Coyote Springs | 7500 | 7500 | 44 | 170 | 170 |
| Beatys Butte | 3750 | 7500 | 54 | 69 | 139 |
| Alturas | 3500 | 3500 | 72 | 49 | 49 |
| Sugar Hill | 2833 | 2833 | 75 | 38 | 38 |
| Hawks Valley | 2667 | 2667 | 27 | 99 | 99 |
| Buck Mountain | 2500 | 2500 | 71 | 35 | 35 |
| Cowhead Lake | 1600 | 1600 | 46 | 35 | 35 |
| Long Valley | 867 | 650 | 18 | 48 | 36 |
| Badger Creek | 813 | 542 | 25 | 33 | 22 |
| Mosquito Lake | 467 | 467 | 31 | 15 | 15 |
| Logo | 88 | 88 | 71 | 1 | 1 |

Table 3.5. Gravity Model Rankings Results. Ranks Presented from Highest to Lowest in each Column.

| **CCD Locality WST Source Frequencies (*n)*** | **Predicted Rank (Scarcity: >6.5 cm)** | **Predicted Rank (Scarcity: >12 cm)** |
|---|---|---|
| Beatys Butte (84) | Coyote Springs FGV | Coyote Springs FGV/Beatys Butte |
| Cowhead Lake (44) | Hawks Valley | Hawks Valley |
| Badger Creek (32) | Beatys Butte | Alturas FGV |
| Mosquito Lake (29) | Alturas FGV | Sugar Hill |
| Buck Mountain (28) | Long Valley | Long Valley |
| Hawks Valley (18) | Sugar Hill | Buck Mountain/Cowhead Lake |
| Coyote Springs (14) | Buck Mountain/Cowhead Lake | Badger Creek |
| Long Valley (12) | Badger Creek | Mosquito Lake |
| Alturas (6) | Mosquito Lake | Logo |
| Sugar Hill (4) | Logo | |
| Logo (0) | | |

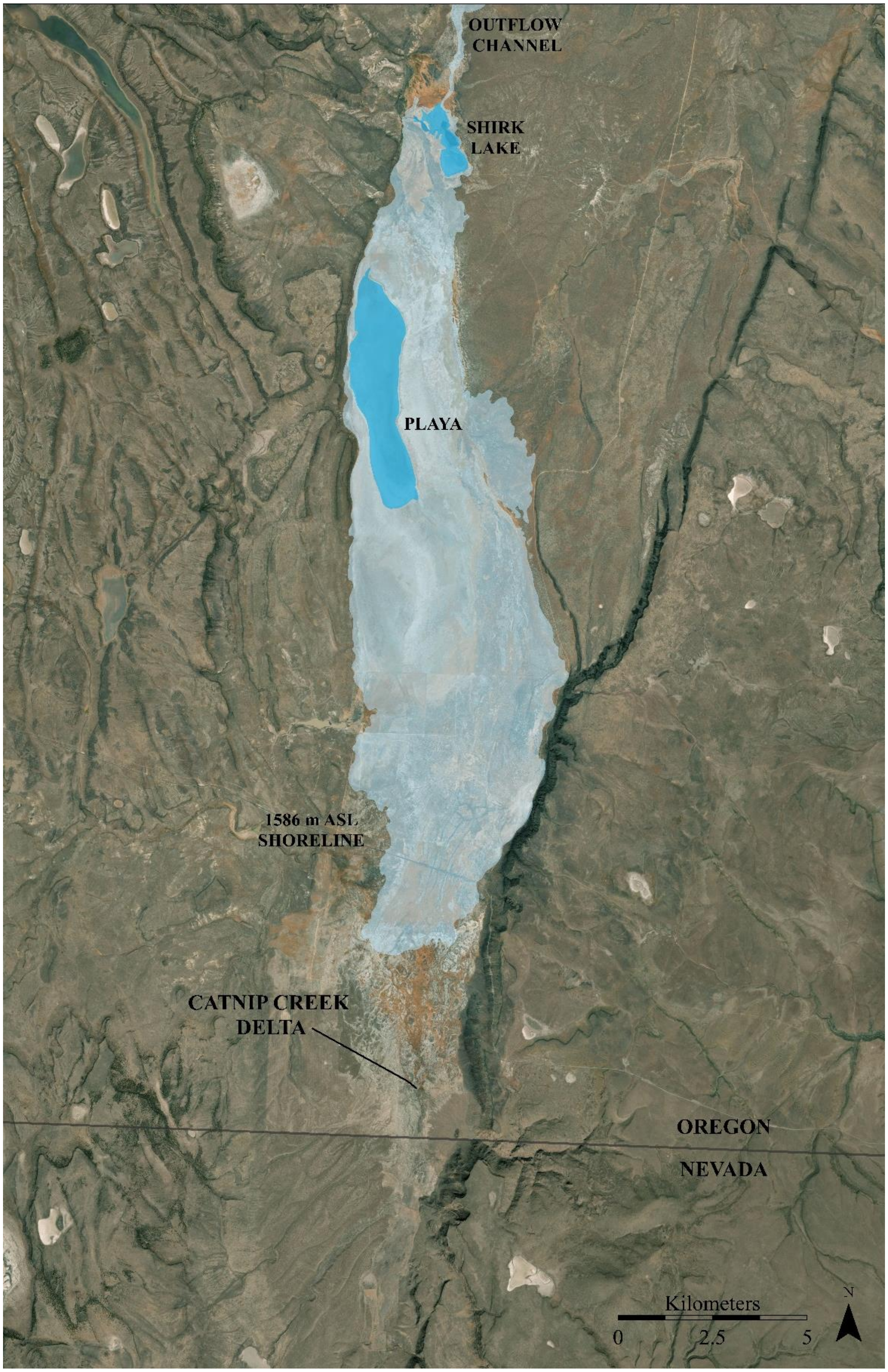

Figure 3.1. Overview of Guano Valley, Oregon (adapted from Reaux et al. 2018).

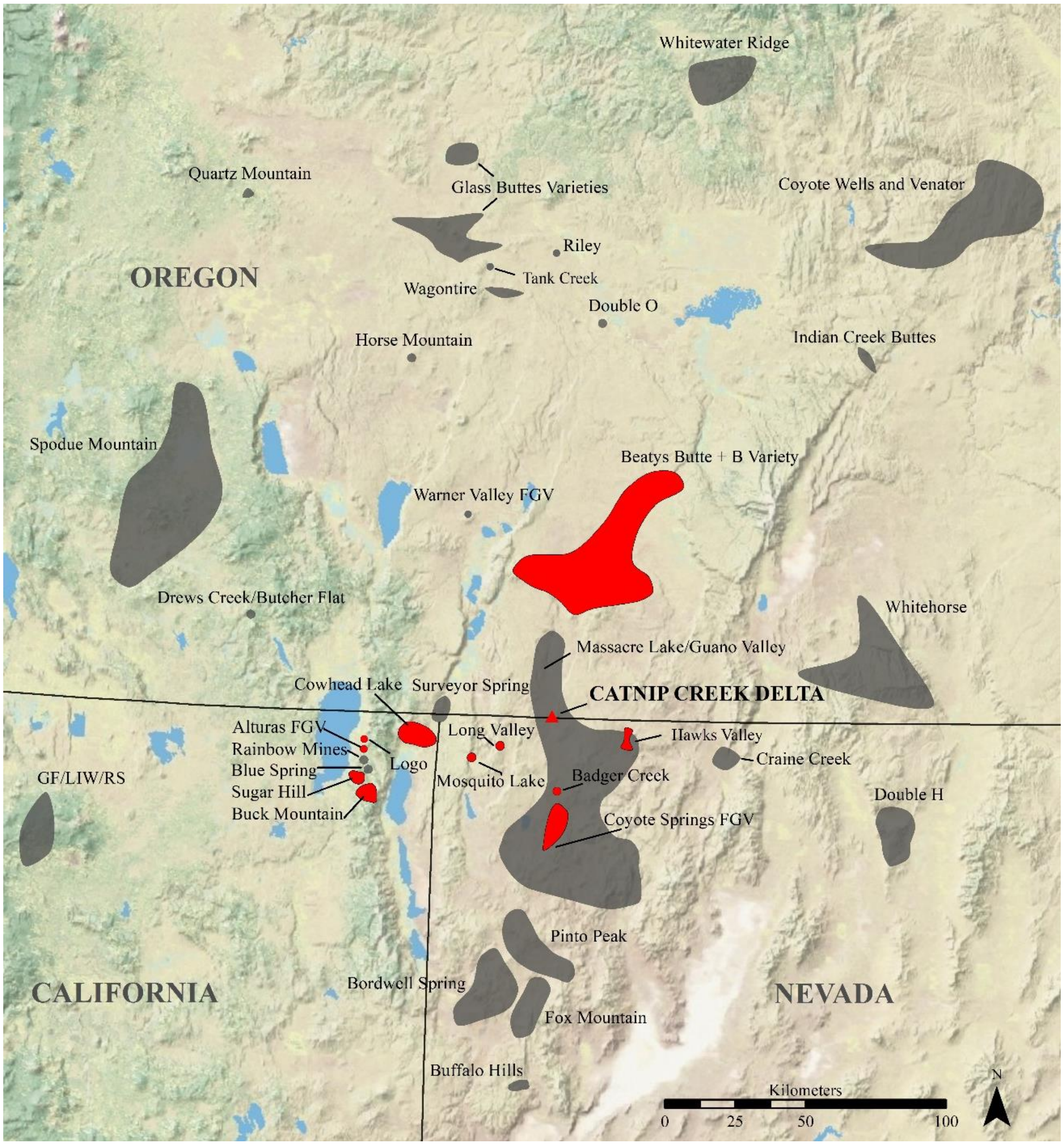

Figure 3.2. Location of Catnip Creek Delta and toolstone sources represented in the CCD assemblage. Sources featured in this study are highlighted in red.

Figure 3.3. Toolstone varieties discussed in the text: (top left) Buck Mountain mahogany obsidian; (bottom left) Buck Mountain banded obsidian; (middle) inclusions in Mosquito Lake obsidian; (top right) poor-quality Logo obsidian; and (bottom right) Cowhead Lake obsidian cobble.

Figure 3.4. Examples of toolstone source variability: (top left) dense concentration of large Alturas FGV clasts; (bottom left) pebble and small cobble dominated Badger Creek source; (middle) high density Coyote Springs FGV; (top right) high density of large, rounded cobbles covered in forest duff at the Sugar Hill source; and (bottom right) small rounded cobbles in a dry creek bed at the Long Valley source.

# Chapter 4:

# PALEOINDIAN AND EARLY ARCHAIC TERRITORIALITY AND INTER-SITE CONNECTIVITY IN THE NORTHWESTERN GREAT BASIN

*Source provenance data have provided considerable insights into prehistoric mobility, territoriality, and socioeconomic interactions in the northwestern Great Basin. Recent studies in Oregon's Warner and Guano valleys suggest that Western Stemmed Tradition (WST) groups in those neighboring basins primarily procured toolstone from different sources throughout the region. This difference may reflect the presence of multiple Paleoindian territories during the Early Holocene. In this study, I conduct a social network analysis to explore regional lithic conveyance networks, the connectivity of WST sites, and how networks changed during the Early-Middle Holocene transition (EMHT). My results demonstrate that sites were highly connected during the Terminal Pleistocene and Early Holocene and that groups freely moved and/or exchanged toolstone throughout the northwestern Great Basin. These findings counter previous studies suggesting that a territorial boundary existed along the Oregon/Nevada border. Connectivity fell sharply during EMHT, likely in response to deteriorating climatic conditions and changing settlement-subsistence strategies.*

## Introduction

Studies of Terminal Pleistocene/Early Holocene (TP/EH [~16,000-8300 cal BP]) mobility, territoriality, and socioeconomic interactions are common in the Great Basin (Jamaldin 2018; Jones et al. 2003; Madsen 2007; Newlander 2012; Page 2008; Page and Duke 2015; Smith 2010). Researchers have explored these topics in some depth due to an abundance of Paleoindian lithic assemblages and toolstone sources amenable to provenance analysis. Over the past decade, the Great Basin Paleoindian Research Unit (GBPRU) at the University of Nevada, Reno has conducted fieldwork in Warner and Guano valleys in southeastern Oregon (Reaux et al. 2018; Smith et al. 2015; Wriston and Smith 2017). Although these valleys lie adjacent to one another and are separated by only ~22 km, the toolstone source profiles of their Paleoindian assemblages are different. Assemblages from North Warner Valley contain high proportions of toolstone from the Fort Rock and Abert-Chewaucan basins to the north (Smith et al. 2015). Assemblages from Guano Valley's Catnip Creek Delta (CCD) Locality possess high proportions of toolstone from Nevada's High Rock Country to the south (Reaux et al. 2018). In that regard, the CCD Locality source profile is similar to those from presumably contemporary sites like Last Supper Cave (Felling 2015; Layton 1970; Smith 2008), Hanging Rock Shelter (Smith et al. 2011), and the Parman Localities (Smith 2006, 2010).

Elsewhere, my colleagues and I suggested that these different toolstone conveyance patterns may reflect regional populations who operated within separate foraging ranges in the northwestern Great Basin (Reaux et al. 2018). In this paper, I further examine this idea through a network analysis of Western Stemmed Tradition

(WST) artifacts. Network analyses provide a mathematical means to examine the connections between actors (in this case, archaeological assemblages) in a social network (Golitko et al. 2012). I test for the presence of multiple regional lithic networks and determine the overall connectivity between WST sites in the region. Additionally, I explore how and why lithic networks changed during the Early-Middle Holocene transition (EMHT).

## Background

The WST represents the oldest and most widespread Paleoindian techno-complex in the Intermountain West (Smith et al. 2020a). In the northwestern Great Basin, it is represented by: (1) stemmed bifacial tools that served as hunting and butchering implements (Lafayette and Smith 2012); (2) small sites that lack evidence of long-term occupations, often situated near relict wetlands (Elston et al. 2014); (3) diverse faunal assemblages (Smith and Barker 2017); (4) bone and wood tools, shell beads, and a variety of textiles (Camp 2017; Smith and Barker 2017); and (5) toolstone source profiles that suggest people carried toolstone or finished tools substantial distances (Reaux et al. 2018; Smith 2010).

Models of WST settlement-subsistence tend to fall into two categories (see Chapter 2). The *Wetland Transient Model* posits that groups were residentially mobile and frequently moved camps between wetlands (Elston and Zeanah 2002; Elston et al. 2014; Graf 2001; Jones et al. 2003, 2012; Smith 2010). The *Wetland Stable Model* suggests that groups were less mobile and located longer-term residential camps around wetlands, moved infrequently, and procured some resources through long-distance logistical forays (Duke and Young 2007; Madsen 2007; Willig 1989). Current evidence suggests that WST settlement-subsistence strategies in the northwestern Great Basin were more closely aligned with the *Wetland Transient Model* (Jamaldin 2018; Jones et al. 2003; Smith 2006, 2011; Smith and Barker 2017; see also Chapter 2).

While WST groups may have been mobile, it remains unclear how much ground they covered during seasonal, annual, and/or lifetime movements. Source provenance data offer some sense of early foraging ranges, and Jones et al.'s (2003, 2012) lithic conveyance zone (LCZ) concept has been central to such studies for the past two decades. In short, LCZs are visual conveyance models based on the directions and distances of toolstone movement. They encompass areas within which groups procured and discarded toolstone. In their initial study, Jones et al. (2003) hypothesized that five large LCZs covered the Great Basin during the TP/EH. They suggested that the zones delineated the foraging territories of mobile groups. Jones et al. (2003) divided the northwestern Great Basin into two zones based on a small number of artifacts from a few sites. A northern zone encompassed southeastern Oregon and a western zone encompassed northwestern Nevada.

Subsequent studies took issue with the size of Jones et al.'s (2003) original LCZs, which in some cases covered nearly 100,000 km$^2$ and exceeded the territories of most documented foraging societies (Kelly 2013). Smith (2010) explored this issue using additional sourcing data from northwestern Nevada and revised Jones et al.'s (2003) western LCZ into two smaller zones that were more in line with ethnographic territories. Like Jones et al. (2003, 2012), Smith (2010) posited that the northwestern Great Basin contained two LCZs with a boundary near the Oregon and Nevada border. Madsen (2007) argued that LCZs could reflect areas covered by logistical parties or dispersed groups coming together periodically rather than residentially mobile groups. Newlander (2012, 2015) suggested that LCZs may reflect both foraging ranges and exchange networks. Finally, Smith and Harvey (2018) argued that the LCZ concept itself was problematic due to issues of equifinality and sampling biases. They consequently proposed that researchers should consider new approaches to interpreting source provenance data.

### *The Early-Middle Holocene Transition*

By 8300 cal BP, WST technology had fallen out of use (Smith et al. 2020a; Smith and Barker 2017). Its disappearance roughly coincides with onset of the Middle Holocene. Although climate was variable throughout the Middle Holocene, it was generally hotter and drier, especially early on, when compared to the periods that preceded or followed it (Grayson 2011; Wriston 2009; Young and Rhode 2016). Most pluvial lakes and wetlands receded or desiccated completely (Grayson 2011; Wriston 2009). During the initial Middle Holocene (~8300-5800 cal BP), Northern Side-notched points (NSN) replaced stemmed and concave base points, marking the transition to the Early Archaic period in the northwestern Great Basin (Jenkins et al. 2004a). Reductions in toolstone conveyance (Smith 2010), the appearance of residential structures (Helzer 2004; Jenkins 2004; O’Connell 1975; Wingard 1999), and a broadening diet that included more small seeds (Simms 2008) suggest that Early Archaic groups adopted a more residentially stable lifestyle in the northwestern Great Basin. Most Early Archaic sites occur in similar settings as WST sites (Aikens et al. 1977; Layton 1972a, 1972b; O’Connell 1975; Pratt 2015), although people sometimes shifted site locations in response to lake and wetland fluctuations. Human populations were probably lower during the Middle Holocene than at any other time (Louderback et al. 2010).

## Social Network Analysis

Previous research has established that toolstone conveyance in the northwestern Great Basin changed across the EMHT. Artifact transport distances and toolstone richness (i.e., the number of unique sources in an assemblage) both decreased during the initial Middle Holocene (King 2016; McGuire 2002; Smith 2010). What remains unknown is how the overall connectivity of the region and the position of individual sites in broader systems shifted during this time. Social network analysis (SNA) offers a means of exploring these topics. SNA is a diverse field grounded in graph theory and matrix algebra (Borgatti et al. 2009; Brughmans 2010, 2013). The primary goal of SNA is to explore the structure of relationships between actors (e.g., people, objects, ideas) in a network (Borgatii et al. 2009; Brughmans 2010; Golitko et al. 2012). A network is a set of actors (i.e., nodes) and the connections (i.e., edges) between them (Golitko et al. 2015). Researchers have applied SNA across the social and physical sciences to explore the network structures of a variety of subjects such as the internet, the human brain, and global trade (Brughmans 2010). Archaeologists have also employed SNA. For example, Gotliko et al. (2012) examined the decline of the Classic Maya through shifts in obsidian trade networks. Sindbæk (2007) explored the appearance of Scandinavian Viking Age towns and revealed a possible hierarchy of sites based on the volume of imported raw materials and goods. Buchanan et al. (2017, 2019a, 2019b) compared Clovis and Folsom assemblages to explore Paleoindian social networks, lithic technological organization, and social learning. This study represents the first application of SNA to lithic assemblages in the Great Basin, and here I seek to determine: (1) if there were multiple WST lithic networks in the northwestern Great Basin; (2) the interconnectedness of WST sites and groups in the region; and (3) if and how regional connectivity and lithic networks changed across the EMHT.

### *Materials and Methods*

I investigated the connectivity of sites based on the number of toolstone sources they share. For the WST analysis, I used published data for 19 assemblages from the northwestern Great Basin (Table 4.1)[1]. These assemblages primarily come from sites in the Fort Rock and Abert-Chewaucan basins in south-central Oregon and the High Rock Country of northwestern Nevada (Figure 4.1). Many assemblages come from surface contexts and are dated only by typological cross-dating. Others come from stratified sites but the degree to which the deposits were mixed remains unknown. As such, I only included time-sensitive projectile points and crescents. If a site reliably contained both Terminal Pleistocene and Early Holocene assemblages, I included them as separate datasets. Most assemblages likely date to the Early Holocene (~11,600-8300 cal BP) based on the prevalence of Parman, Cougar Mountain, and Windust stemmed points

(Rosencrance 2019). I did not include artifacts that could not be assigned to known sources.

To analyze Early Archaic lithic networks, I initially sought to use NSN points from the same sites from which the WST sample is derived; however, only seven sites contained both point types. Therefore, to bolster my Early Archaic sample, I included three additional NSN assemblages from sites in the same general area (Table 4.2). While some of the Early Archaic assemblages contain fewer than 10 sourced NSN points (see Appendix), I nevertheless included them due to a paucity of sourced Early Archaic points in the region. Although my study focuses on the number of sources shared between assemblages and not simply artifact counts, larger assemblages do tend to contain more diverse source profiles (Buchanan et al. 2017) and future studies should include a larger Early Archaic sample if possible.

I used UCINET version 6.232 to carry out my SNA (Borgatti et al. 2002). I designated each assemblage as a node to construct the networks. If nodes shared a toolstone type, then they were linked by an edge (symmetric, undirected). The more toolstone types two nodes (sites) share, the stronger their strength of tie or connection is to one another. To determine if multiple WST and Early Archaic networks existed, I used the UCINET software to identify the presence of network components and isolates. Network components are portions of a network that are disconnected from each other (Hanneman and Riddle 2005). If multiple isolated WST or Early Archaic populations operated within the northwestern Great Basin then the SNA should identify multiple network components. Isolates represent single nodes that are not connected to a network because they do not share a common toolstone type with another node.

To examine the connectivity of sites, I calculated the average density of each network. The average density of a network is the proportion of all possible ties to actual ties in a network (Buchanan et al. 2019a). A high-density measurement indicates that raw material and, potentially, information and genes, within the network flow more easily (Buchanan et al. 2019a; Hanneman and Riddle 2005). For example, in a large undergraduate lecture course, the total number of potential connections or relationships between students is high, but the number of students who actually know each other is likely low. Inversely, in a small graduate seminar, the number of actual relationships between students, relative to potential relationships, is likely quite high. In this scenario, the undergraduate course has a low average density, whereas the graduate seminar has a high average density and represents a highly connected network. Here, I use the average density measurement to help determine if toolstone procurement, site occupation, and exchange were restricted by socio-political relationships/boundaries or other factors (e.g., settlement-subsistence strategies).

Finally, I calculated the degree (Freeman's approach) and betweenness (flow) of each assemblage. Degree and betweenness help identify which nodes (sites) are the most important or influential within a network. Degree refers to the total number of edges that are connected to a node. A site with a high degree score indicates that it shares numerous toolstone types with many other sites, suggesting that it was a central location of occupation and/or exchange within the network. Betweenness measures the amount of times a node falls upon the shortest (geodesic) pathway between other pairs of nodes (Hanneman and Riddle 2005). For example, suppose that people from Site A want to relocate to Site C but the distance is too great to travel in one day so they stop at Site B.

Likewise, suppose that people from Site D want to move to Site E but they also must stop at Site B during their trip. Because Site B is instrumental in the movement of people between these sites, it possesses high betweenness and, consequently, a greater position of importance within the network. These measures are impacted by sampling bias but betweenness less so than degree (Wey et al. 2008). Because sample size varies, sometimes significantly, I examined each assemblage and its corresponding dataset to determine if sampling influenced my results.

Using Spearman's rank-order correlation coefficient, I found a strong relationship ($p<0.05$) between sample size and degree in the WST ($r_s=0.812$, $p=2E\text{-}05$) and Early Archaic ($r_s=0.815$, $p=0.004$) datasets. Betweenness was also correlated with sample size in the WST assemblages ($r_s=0.84$, $p=1E\text{-}05$) but not in the Early Archaic ($r_s=0.53$, $p=0.12$); however, simple scatterplots illustrated that both datasets possessed a logarithmic trend between degree (Figure 4.2) and betweenness and sample size (excluding Early Archaic betweenness). This trend showed exponential growth within the smaller assemblages but as sample size increased there was a plateau in the relationship. I explored this further and found that when I removed WST assemblages (see Table 4.1) with >100 artifacts, there was no significant relationship between degree ($r_s=0.532$, $p=0.062$) or betweenness ($r_s=0.51$, $p=.077$) and sample size. This was also true for the Early Archaic degree measurements when I removed the much larger Last Supper Cave and CCD Locality assemblages from the dataset ($r_s=0.65$, $p=0.081$). These findings indicate that the degree/betweenness measures for WST assemblages with <100 artifacts and Early Archaic assemblages with <32 artifacts are not significantly impacted by sample size. Conversely, the measurements for the larger WST (>100 artifacts) and Early

Archaic (>32 artifacts) assemblages cannot be confirmed to be not significantly impacted by sample size without additional assemblages of similar size to determine if this trend is real or a product of incomplete sampling.

To visualize the networks and conduct additional graphical analyses, I used NetDraw version 2.089 (Borgatti 2002) within the UCINET software. To investigate the presence of sub-components within each network, I conducted a K-Core analysis within NetDraw. K-Core analyses identify tightly interlinked groups within a network (Hanneman and Riddle 2005). If K-Cores are present within the network, it suggests that there are groups of sites that are more strongly connected to one another than they are with other groups of sites in the region. These K-Cores could signify the presence of different regional groups that, while still connected in some form (e.g., trade, marriage), may have operated in separate foraging territories or possesses differential access to certain toolstone sources. I also conducted a Block and Cutpoint analysis, which identifies nodes that if removed would cause the network to separate into unconnected components (Hanneman and Riddle 2005). This method serves a similar function as the K-Core analysis but also identifies specific sites that may have been an important point of connection between possible sub-populations within a network. To visualize the WST network (Figure 4.2), I applied the Scaling/Ordination method (adjusted to the nearest Euclidean) based on similarities in the strength of connections (ties) between assemblages. Importantly, the NetDraw visualization methods only provide a means to illustrate network data in a two-dimensional space and do not affect analyses or measurement results.

# Results

## *WST Network Analysis*

The WST network analysis identified a single network component comprised of all 19 assemblages and no isolates. K-Core and other subgroup analyses did not locate any sub-components within the network. The average density of the WST lithic network is 0.947, meaning that ~95% of all possible ties are present and that the network is highly connected (a density of 1 represents a fully connected network). This suggests that during the TP/EH there were no boundaries confining toolstone conveyance. Table 4.3 presents the degree and betweenness measures for each assemblage. The CCD Locality in Guano Valley has the highest degree (157) and betweenness (33) measurements, suggesting that it is likely a central site in the network and may have been an important point of connection between central Oregon and High Rock Country sites. The Terminal Pleistocene Paisley Caves (35LK3400) assemblage and the Early Holocene Paulina Lake (35DS34 Components 1-2) assemblage possess the lowest degree (32 and 43, respectively) and betweenness (6 and 8, respectively) scores. The Terminal Pleistocene assemblage at the Paisley Caves is the oldest WST occupation in the Great Basin (Jenkins et al. 2014). Although its low measurements are dictated by its limited sample size (*n*=7), its connection to High Rock Country sites indicates that the two sub-regions were connected very early in time. Lastly, the Paulina Lake Site (35DS34 Components 1-2) is predominantly comprised of Windust points (Connolly and Jenkins 1999). Windust points are technologically and morphologically different than other WST types and researchers debate their placement within the WST (Beck and Jones 2009, 2014). Windust points resemble Cody and Alberta points mostly found east of the Rocky Mountains, and Amick (2013; also see Hartman 2019) has suggested that they mark incursions into the Great Basin by Plains bison hunters. Given this, the Paulina Lake Site may be weakly connected to the broader WST network because its occupants were largely unaffiliated with Early Holocene Great Basin populations, lacked a detailed knowledge of the lithic landscape, and/or possessed different toolstone procurement strategies to those employed by groups using other types of stemmed points.

Figure 4.3 displays the WST lithic network using the Scaling/Ordination method within NetDraw. Nodes in this method are arranged based on the similarities between their strength of ties. The strength of ties is also displayed by color and line thickness (thicker lines reflect stronger ties). Assemblages from the High Rock Country and central Oregon spatially separate from each other, albeit not dramatically, within the network. Despite the lack of identifiable sub-components, the sites in each sub-region are clearly more strongly connected with each other than with those in the other sub-region. Excluding the CCD Locality, most High Rock Country sites share just 1-4 sources with central Oregon sites whereas they share 5-16 sources with other nearby sites. This pattern also holds true for most central Oregon assemblages. The source profiles from sites in each sub-region are also dominated by toolstone found within that sub-region (see Appendix). In most cases, the strength of ties between sites is likely the result of their proximity to one another and to particular sources (i.e., distance-decay [Renfrew 1977]); however, this cannot be said for the CCD Locality and North Warner Valley assemblages. Those assemblages contain at least 10 shared sources with multiple sites in both sub-regions. North Warner Valley is also more strongly linked to the CCD Locality than any other site in the network. This suggests that North Warner Valley and the CCD Locality were connected and likely mark locations used by WST groups moving between the two sub-regions (see below).

### *Early Archaic Network Analysis*

The Early Archaic network is comprised of a single network component that includes all sites and no isolates. The average density of the network is 0.433, less than half that of the WST network. Table 4.4 shows the degree and betweenness measures for Early Archaic sites. The CCD Locality and Last Supper Cave have the highest degree scores, although this may be due to their large sample sizes. The betweenness measures display some contrasting results, particularly that Buffalo Flat[2] possesses the highest betweenness measurement. Buffalo Flat's high betweenness is likely due to the fact that it is the only central Oregon site to contain High Rock Country sources and not a shift in the site's overall importance to the network (Oetting 1993). The CCD Locality's betweenness is also high, suggesting that it was an important site in the network. Conversely, Last Supper Cave's betweenness measure is considerably lower than its degree, indicating that it was likely not as central to the movement of toolstone or people within the network. This may be related to the site's location deep in a canyon and use as a short-term logistical hunting location (Felling 2015).

Figure 4.4 displays the Early Archaic lithic network resulting from the K-Core analysis. The K-Core analysis identified two K-Cores and a single isolate. One K-Core includes all sites within the High Rock Country and the other is restricted to sites in central Oregon. The North Warner Valley assemblage is an isolate separate from both K-Cores. The Block and Cutpoint analysis identified Buffalo Flat as a cutpoint node. Thus, if it was removed the network would form two separate blocks or bi-components. The first block contains the High Rock Country sites and the North Warner Valley assemblage, and the second block contains the central Oregon sites. Buffalo Flat and the CCD Locality are the only two assemblages in each K-Core to share a toolstone type. No High Rock Country sources occur in any central Oregon assemblages. Lastly, the North Warner Valley Early Archaic assemblage is also most strongly tied to the CCD Locality, further suggesting that the neighboring valleys were connected.

## Discussion

During the TP/EH, the northwestern Great Basin was either occupied by a few groups who ranged through large foraging areas (*sensu* Jones et al. 2003) or many groups who ranged through smaller foraging areas but were in regular contact with each another. The high-density measurement (0.947) and lack of sub-components within the network suggest that groups' movements and the toolstone procurement and/or exchange that accompanied them were not restricted by socio-political or geographical boundaries. Furthermore, it indicates that Jones et al.'s (2003) original northern LCZ and Smith's (2010) northwestern Nevada LCZ actually reflect a single network comparable in size to those which Jones et al. (2003, 2012) envisioned for the central and eastern Great Basin. This high connectivity may have been in part a function of low population densities, which would have both allowed groups to range through larger foraging areas due to less resource competition (Elston et al. 2014; Jones et al. 2003) and necessitated more distant travels to acquire things like information and mates (MacDonald and Hewlett 1999; Newlander 2017; Speth et al. 2013; Whallon 2006).

In general, most WST assemblages in the High Rock Country and central Oregon do not share strong ties. This is not surprising given that these sites are often separated by 100-200 km and toolstone sources are plentiful in both areas. This is not the case with the CCD Locality and North Warner Valley. Those sites contain strong connections with numerous sites in both sub-regions as well as with each other. A high frequency of central Oregon sources in the North Warner Valley assemblage suggests that groups likely last visited that region before moving south towards Warner Valley (Smith et al. 2015). In North Warner Valley, Beatys Butte (16%) and Horse Mountain (20%) obsidian, located to the east (~33 km) and northwest (~57 km), respectively, are the prevalent toolstone types (Smith et al. 2015). Beatys Butte and Horse Mountain are also the most common northerly located sources in the CCD Locality assemblage (see Chapter 2). Given these similarities and the high proportion (15%) of Beatys Butte obsidian in the CCD Locality, groups from central Oregon may have traveled to North Warner Valley, then to Guano Valley, and ultimately into the High Rock Country. The high number (19%) of High Rock Country sources in the CCD Locality also indicates groups probably moved from south to north into Guano Valley. Likewise, the presence of High Rock Country sources in North Warner Valley may represent groups heading north into central Oregon. The CCD Locality is the densest concentration of WST artifacts in the northwestern Great Basin, and elsewhere (see Chapter 2) I have argued that it reflects frequent short-term occupations by mobile groups. The CCD Locality's high degree and betweenness measurements, source profile patterns, and sheer density of lithic detritus suggest that it may have been an important stopping place for groups moving between central Oregon's lake basins and Nevada's High Rock Country.

Alternatively, the sub-regions lay within largely separate foraging ranges connected via a wide-reaching trade network centered on the CCD Locality. While the K-Core analysis did separate the two sub-regions during the EMHT, providing some support for this possibility, the CCD Locality record does not suggest that Guano Valley witnessed population aggregations (see Chapter 2). Unfortunately, determining whether toolstone was acquired through direct procurement, trade, or a combination of processes is not possible using source provenance data alone (Hughes 2011). Nevertheless, I agree with Smith (2010) that extensive toolstone exchange was likely uncommon given the rich lithic landscape of the northwestern Great Basin. Although they cannot speak directly to TP/EH lifeways, regional ethnographic accounts indicate that toolstone there was common enough that acquiring it via trade was not necessary despite that people were operating within restricted territories due to Euro-American expansion (Kelly 1932). However, WST groups likely operated as dispersed bands and long-distance movements were, at times, likely essential to acquire information and mates (MacDonald 1998; MacDonald and Hewlett 1999; Newlander 2012, 2017; Whallon 2006). The movement and/or exchange of toolstone for the purpose of maintaining social networks likely accounts for some of the connections between the sub-regions and the high connectivity of the network.

Finally, the distribution of food resources in the northwestern Great Basin is unlikely to have promoted rigid territorial boundaries. Paleoindians targeted a wide range of animals and plants in the region (Smith and Barker 2017). Although wetlands were abundant during the Terminal Pleistocene and, in some valleys, during the Early Holocene, their productivity probably fluctuated on a seasonal (especially in the winter) and annual basis (Grayson 2011). When resources are dispersed and unpredictable, as was likely the case during the TP/EH (Grayson 2011, 2016), foragers tend to be mobile and are unlikely to establish and defend territorial boundaries (Dyson-Hudson and Smith 1978; Kelly 2013). While ethnographic groups in the northwestern Great Basin operated within territories, they rarely defended them, and generally granted access to outsiders who asked permission (Kelly 1932). Territorial conflict did occasionally happen, but it was often restricted to fights between neighboring groups who were not affiliated linguistically (Kelly 1932; Stewart 1941). With the exception of perhaps Clovis, which we still no little about west of the Rocky Mountains, technological and stylistic consistency in both lithic and fiber technology across the northwestern Great Basin does not support the presence of culturally isolated populations during the TP/EH (Camp 2017; Connolly et al. 2016; Smith and Barker 2017). As such, it is doubtful that separate foraging ranges or formal trade networks existed in the northwestern Great Basin. Instead, the high connectivity of the region during the TP/EH is likely the result of limited socio-political and/or geographical boundaries, low populations, and a mobile settlement-subsistence strategy (*sensu* Jones et al. 2003; Smith 2010).

### *Shifting Social Networks During the EMHT*

The Early Archaic network differs markedly from the WST network, suggesting that groups altered their toolstone procurement and, more broadly, their settlement-subsistence regimes during the Middle Holocene. The lower density measurement (0.433) suggests that people became less connected, at least in terms of toolstone conveyance. Early Archaic assemblages contain fewer than half of the toolstone sources present in the WST assemblages (see Appendix). Furthermore, Early Archaic assemblages contain more artifacts made of local toolstone and less artifacts made of distant exotic materials (>50 km). These trends conform to those observed in other sourcing studies and researchers generally posit that changes in toolstone conveyance across the EMHT reflect groups settling-in around remaining wetlands (Delacorte and Basgall 2012; Grayson 2011; King 2016; McGuire 2002; Smith 2010). A common explanation for this settling-in is that as wetlands became less common, the cost of traveling between those that remained increased (Elston et al. 2014; Jones et al. 2003). Increased resource patchiness promoted greater residential stability and expanded diet breadth (Grayson 2011; Simms 2008; Smith 2011). As residential stability increased, Early Archaic groups would have become more reliant on nearby lithic sources, which in the northwestern Great Basin would never be far away. Because tools manufactured from exotic sources are likely to have been exhausted and replaced with local material during longer-term occupations, I do not expect NSN assemblages to possess many artifacts manufactured on distant materials even if Early Archaic groups traversed expansive territories. This produces a lithic network with limited overall connectivity, given the probable absence of extensive toolstone exchange caused by increasing travel costs, low population densities, and the regional abundance of toolstone.

Changes in local conditions across the EMHT also probably altered the viability of some site locations. For example, the CCD Locality possesses the highest degree and betweenness measurements, indicating that it remained an important location for groups into the Middle Holocene, perhaps because it sits along a persistent stream system that drains the adjacent tablelands (Reaux et al. 2018). North Warner Valley and the CCD Locality remained connected and the presence of central Oregon and High Rock Country sources in each assemblage suggests that groups continued to visit these valleys as they moved between the sub-regions. However, Early Archaic material is rare in North Warner Valley and groups likely stopped visiting the area as often after the disappearance of Pluvial Lake Warner (Smith et al. 2015; Wriston and Smith 2017). Other locations that sat adjacent to wetlands during the TP/EH but became dry during the Middle Holocene also appear to have decreased in importance. Hawksy Walksy Valley, the Parman Localities, and the Connley Caves fall into this category. Both Hawksy Walksy Valley (Christian 1997) and Five Mile Flat (Smith 2006) contained small wetlands that likely responded quickly to climate change (Duke and King 2014) and were probably dry for much of the Middle Holocene, thus making them unattractive to Early Archaic groups. Likewise, the marsh below the Connley Caves during the TP/EH retreated (Jenkins et al. 2004b), something that may have contributed to the relatively sporadic use of the caves during the Middle Holocene (Ollivier 2016).

Lastly, the K-Core and Block and Cutpoint analyses show separation of the High Rock Country and central Oregon following the EMHT (see Figure 4.4). This could represent the establishment of socio-political boundaries in the region; however, there is little evidence to support increased territoriality. During the EMHT, the northwestern Great Basin saw changes in lithic and fiber technologies, possibly reflecting the arrival of groups moving south from the Columbia Plateau (Chatters 2012; Connolly and Barker 2004; Delacorte and Basgall 2012; Layton 1985; O'Connell 1975). These shifts occurred across the entire northwestern Great Basin (Chatters 2012; Grayson 2011; O'Connell 1975). As previously stated, among ethnographic groups territorial maintenance largely occurred between different ethnolinguistic groups (Kelly 1932; Steward 1941; but see Thomas 1981). Thus, the reduction in regional connectivity and separation of the two sub-regions was more likely related to changes in settlement-subsistence strategies than the establishment of socio-political boundaries.

## Conclusion

This study represents the first application of SNA in the Great Basin. SNA offers a means of examining the relationships between sites in a quantitative way that LCZs cannot. Ultimately, I have relied on a single dataset, shared toolstone sources, to examine WST and Early Archaic territoriality and exchange. SNA methods are not restricted to source provenance data and future studies can explore these topics using metric data from lithic artifacts (e.g., Buchanan et al. 2019a), textile styles, or rock art motifs. It is important to note that my study is not fully representative of WST and Early Archaic lithic networks in the entire northwestern Great Basin. Although incomplete sampling is almost always an issue in network analyses (Gotliko et al. 2015), additional datasets from beyond the two sub-regions on which I focused may provide a better understanding of WST and Early Archaic networks. Specifically, source provenance data from Oregon's Catlow Valley and Harney and Alvord basins remain scant. Recent work in Guano Valley (Reaux et al. 2018) has shown that early groups acquired toolstone from those areas but more data are needed to determine how they fit into the region's broader lithic and social networks.

Using SNA, I have demonstrated that the northwestern Great Basin was likely characterized by a single highly connected lithic network during the TP/EH. This finding runs counter to previous studies that have suggested that the region contained two networks that separated near the Oregon-Nevada border (Jones et al. 2003; Smith 2010). Paleoindians likely traveled through large ranges, which was facilitated by low population densities, limited resource competition, and a lack of socio-political boundaries. The Early Archaic SNA indicates that the region became less connected during the Middle Holocene. This reduction in regional connectivity was likely caused by increased residential stability that reduced long-distance toolstone conveyance. Continued connections between central Oregon and the High Rock Country indicates that Early Archaic groups still traversed both sub-regions during seasonal, annual, and/or lifetime movements. Shifts in degree/betweenness measurements across the EMHT support the notion that Early Archaic settlement-subsistence was influenced by the disappearance of wetlands. In sum, this study has demonstrated that SNA can move source provenance research forward and provide new insights into prehistoric lifeways in the Great Basin.

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## Notes

1. The Northwest Research Obsidian Studies Laboratory (NWROSL) and Richard Hughes geochemically characterized most assemblages adopted in this study using a standard X-ray fluorescence spectrometer (see references in Table 4.1-2 for detailed methodological descriptions). The GBPRU characterized the remainder of the assemblages (Grund 2020; Jamaldin 2018; Reaux et al. 2018; This Study; see also Chapter 2) using an Olympus Delta DP-6000 portable X-ray fluorescence device. We sent select artifacts that did not match their comparative collection to the NWROSL for further characterization. The Delta model uses a 40 kV Rhodium (Rh) anode X-Ray tube and Olympus Innov-X Systems software. We employed the fundamental parameters calibration provided by the Innov-X software and ran our device using the two-beam (40 and 10 kV) GeoChem mode at 60 seconds per beam. To make source assignments, we analyzed ratios (in parts per million) of the Mid-Z elements strontium (Sr), zirconium (Zr), niobium (Nb), yttrium (Y), and rubidium (Rb) using bivariate scatterplots with R software and discriminant function analysis in the FORDISC program.

2. I combined the Buffalo Flat WST assemblage from multiple sites in the area. These include 35LK1430, 35LK1438, 35LK0963, 35LK1429, 35LK1440, 35LK2095, 35LK2096, 35LK2076, 35LK2068, as well as a number of isolates. The Buffalo Flat Early Archaic assemblage included NSN points from 35LK1181, 35LK1429, 35LK2068, 35LK2098, 35LK2097, and numerous isolates (see Oetting 1993).

Table 4.1. Paleoindian Assemblages used in this Study.

| **Site** | **References** |
|---|---|
| Paisley Caves | Jenkins et al. 2016; Smith et al. 2020b |
| Fort Rock Cave | Jamaldin 2018 |
| Connley Caves | Jamaldin 2018; Smith et al. 2020b; Thatcher 2001 |
| North Warner Valley | Smith et al. 2015 |
| Catnip Creek Delta Locality | Reaux et al. 2018, This Study |
| Hawksy Walksy Valley | Christian 1997; Smith et al. 2020b |
| Last Supper Cave | Felling 2015; Smith 2008, 2009, 2010 |
| Hanging Rock Shelter | Smith et al. 2011 |
| Parman Locality 1+3 | Smith 2006 |
| Parman Locality 2+4 | Smith et al. 2020b |
| Cougar Mountain Cave | Jamaldin 2018 |
| Black Rock Desert West Arm | Smith 2010 |
| Black Rock Desert East Arm | Smith 2010 |
| Rock Creek | Smith 2010 |
| Paulina Lake Site (35DS34) | Connolly and Jenkins 1999 |
| Buffalo Flat[2] | Oetting 1993 |

Table 4.2. Early Archaic Assemblages used in this Study.

| **Site** | **Citation** |
|---|---|
| Carlon Village | Wingard 1999 |
| Boulder Village | Wingard 1999 |
| Connley Caves | Thatcher 2001 |
| Buffalo Flat[2] | Oetting 1993 |
| Northern Warner Valley | Smith et al. 2015 |
| Massacre Lake Basin | Leach 1988 |
| Catnip Creek Delta Locality | This Study; Reaux and Smith 2019 |
| Hawksy Walksy Valley | Grund 2020 |
| Parman Localities | Smith 2010; This Study |
| Last Supper Cave | Grund 2020 |

Table 4.3. Degree and Betweenness Measures for the WST Lithic Network.

| Site | Sample Size | Total Sources | Degree | Betweenness |
|---|---|---|---|---|
| Paisley Caves TP | 7 | 4 | 32 | 6 |
| Fort Rock Cave | 123 | 19 | 99 | 22 |
| Connley Caves Early Holocene | 35 | 16 | 83 | 18 |
| Connley Caves Terminal Pleistocene | 111 | 21 | 111 | 23 |
| Northern Warner Valley | 54 | 22 | 98 | 19 |
| Catnip Creek Delta | 545 | 31 | 157 | 33 |
| Hawksy Walksy Valley | 189 | 19 | 126 | 24 |
| Last Supper Cave | 35 | 9 | 87 | 18 |
| Hanging Rock Shelter | 30 | 11 | 82 | 16 |
| Parman Locality 1 | 29 | 12 | 98 | 19 |
| Parman Locality 2 | 25 | 9 | 73 | 14 |
| Parman Locality 3 | 55 | 12 | 103 | 20 |
| Parman Locality 4 | 27 | 8 | 61 | 11 |
| Cougar Mountain Cave | 113 | 19 | 92 | 21 |
| Black Rock Desert West Arm | 41 | 9 | 78 | 15 |
| Black Rock Desert East Arm | 42 | 10 | 70 | 13 |
| Rock Creek | 31 | 10 | 69 | 11 |
| Paulina Lake Site | 32 | 11 | 43 | 8 |
| Buffalo Flat | 21 | 13 | 56 | 11 |

Table 4.4. Degree and Betweenness Measurements for the Early Archaic Lithic Network.

| Site | Sample Size | Total Sources | Degree | Betweenness |
|---|---|---|---|---|
| Carlon Village | 4 | 4 | 4 | 3 |
| Boulder Village | 4 | 4 | 6 | 8 |
| Connley Caves | 6 | 4 | 4 | 0.3 |
| Buffalo Flat | 14 | 7 | 9 | 42 |
| Northern Warner Valley | 7 | 6 | 6 | 13 |
| Massacre Lake Basin | 10 | 4 | 8 | 3 |
| Catnip Creek Delta | 32 | 8 | 13 | 34 |
| Hawksy Walksy Valley | 10 | 4 | 8 | 4 |
| Parman Localities | 4 | 4 | 8 | 2 |
| Last Supper Cave | 50 | 9 | 12 | 6 |

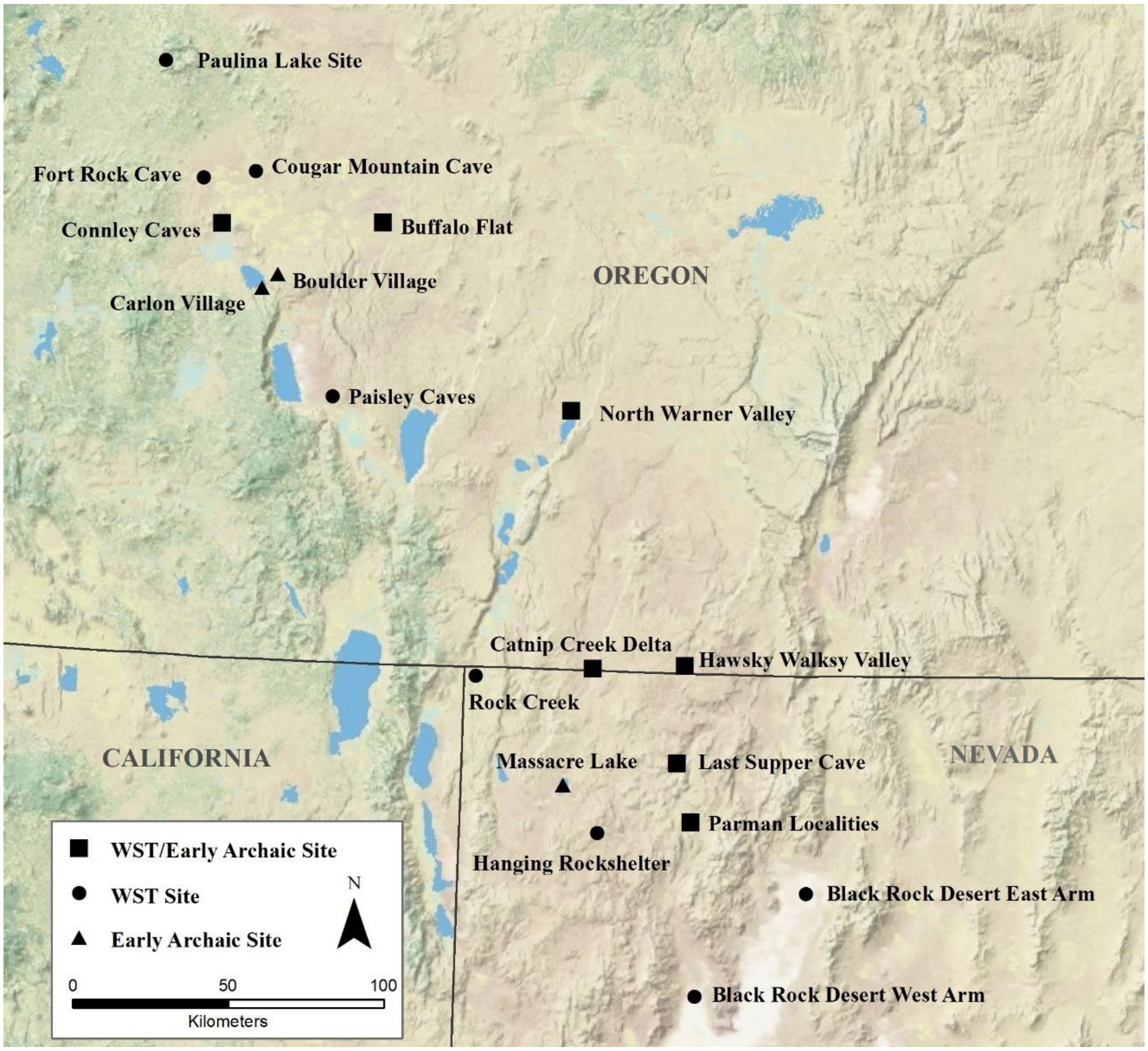

Figure 4.1. The northwestern Great Basin and location of sites in this study.

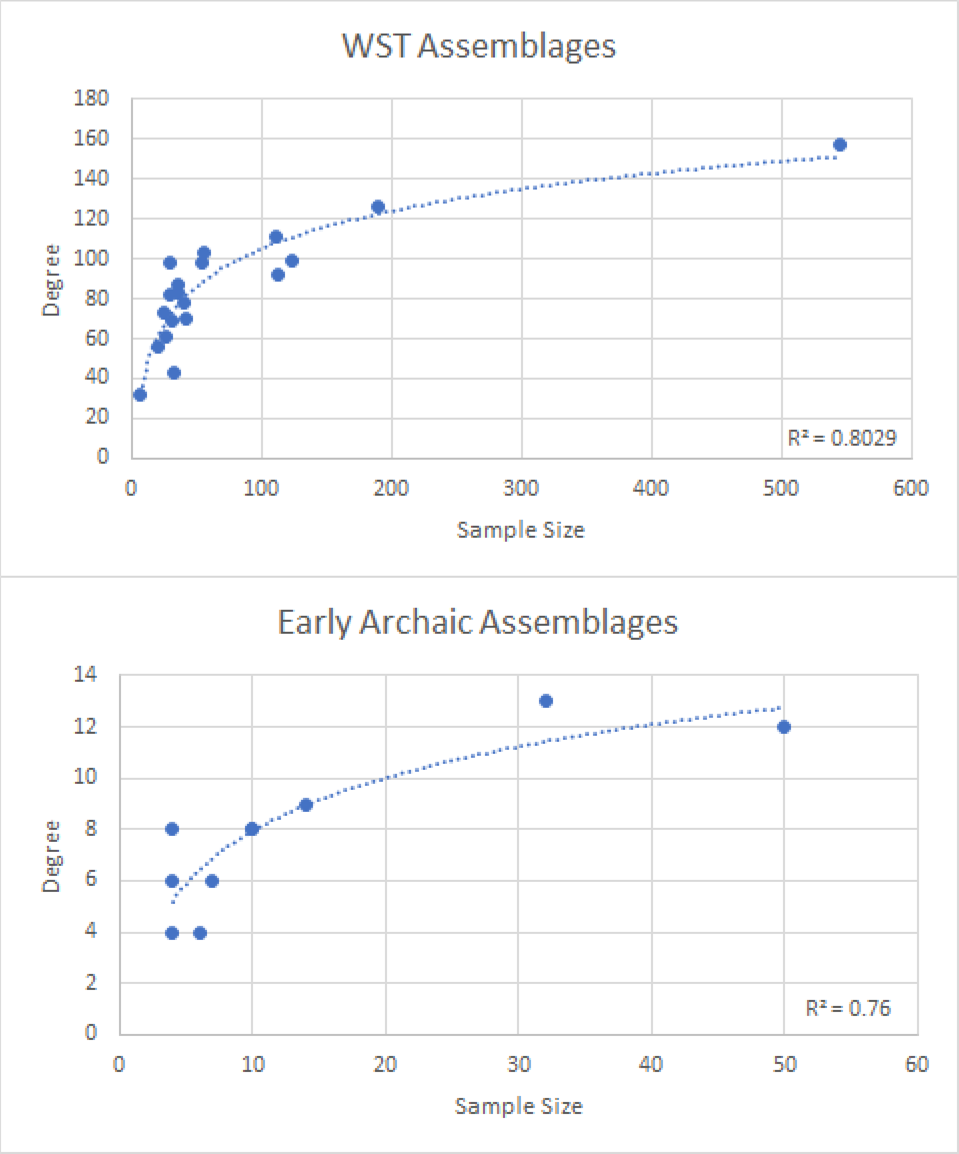

Figure 4.2. Scatterplots showing logarithmic trend in the relationship between degree and sample size.

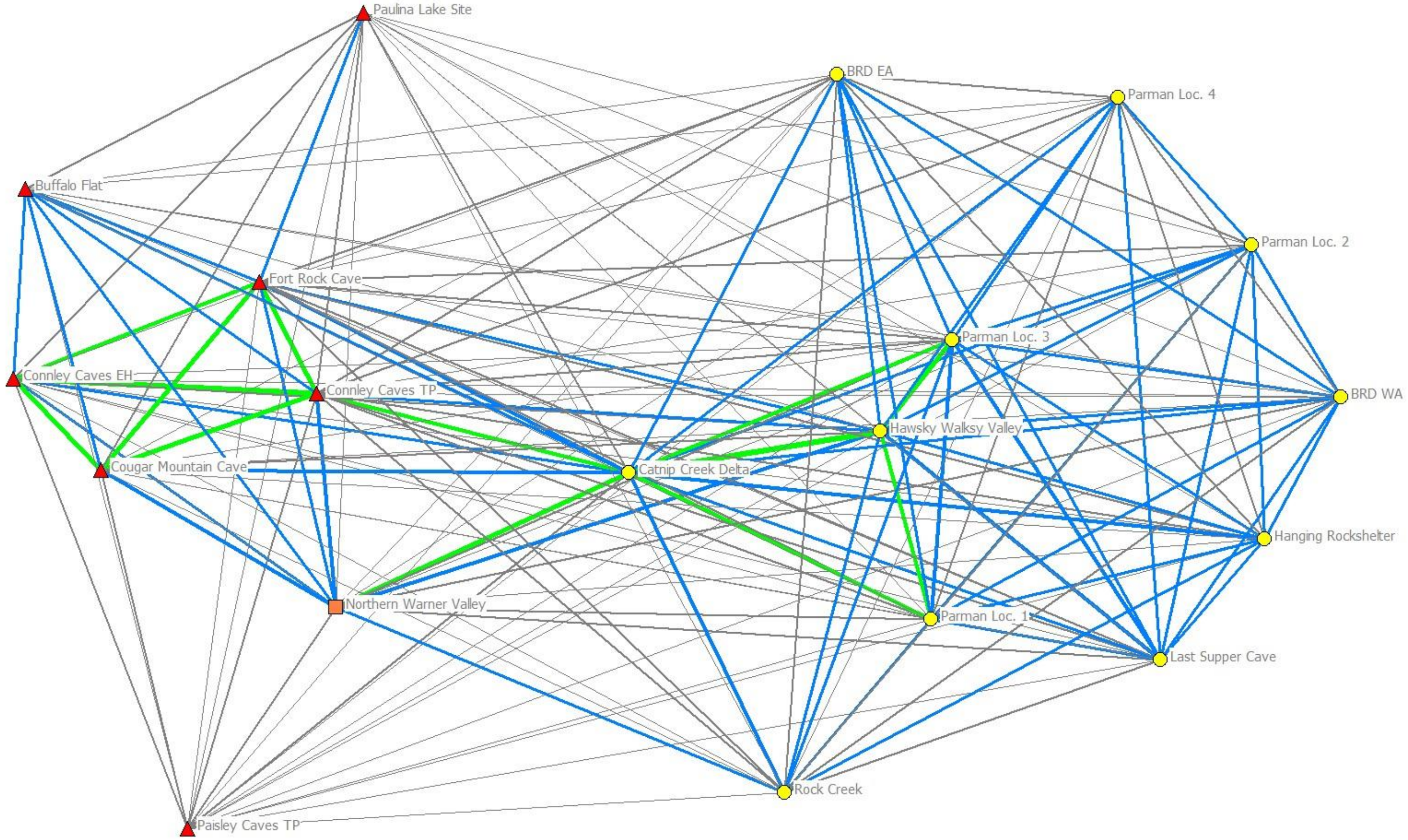

Figure 4.3. The WST Lithic Network. Red triangles represent central Oregon sites and yellow circles represent High Rock Country sites. Warner Valley (orange square) is symbolized differently to mark it as an intermediate location between sub-regions. Edge thickness is based on the strength of ties between nodes (thicker edge = stronger connection). Edge color represents the number of shared sources between assemblages (grey=1-5, blue=6-10, green=10-16). Note: BRD WA/EA=Black Rock Desert West/East Arm (see Smith 2010) and Loc.=Locality.

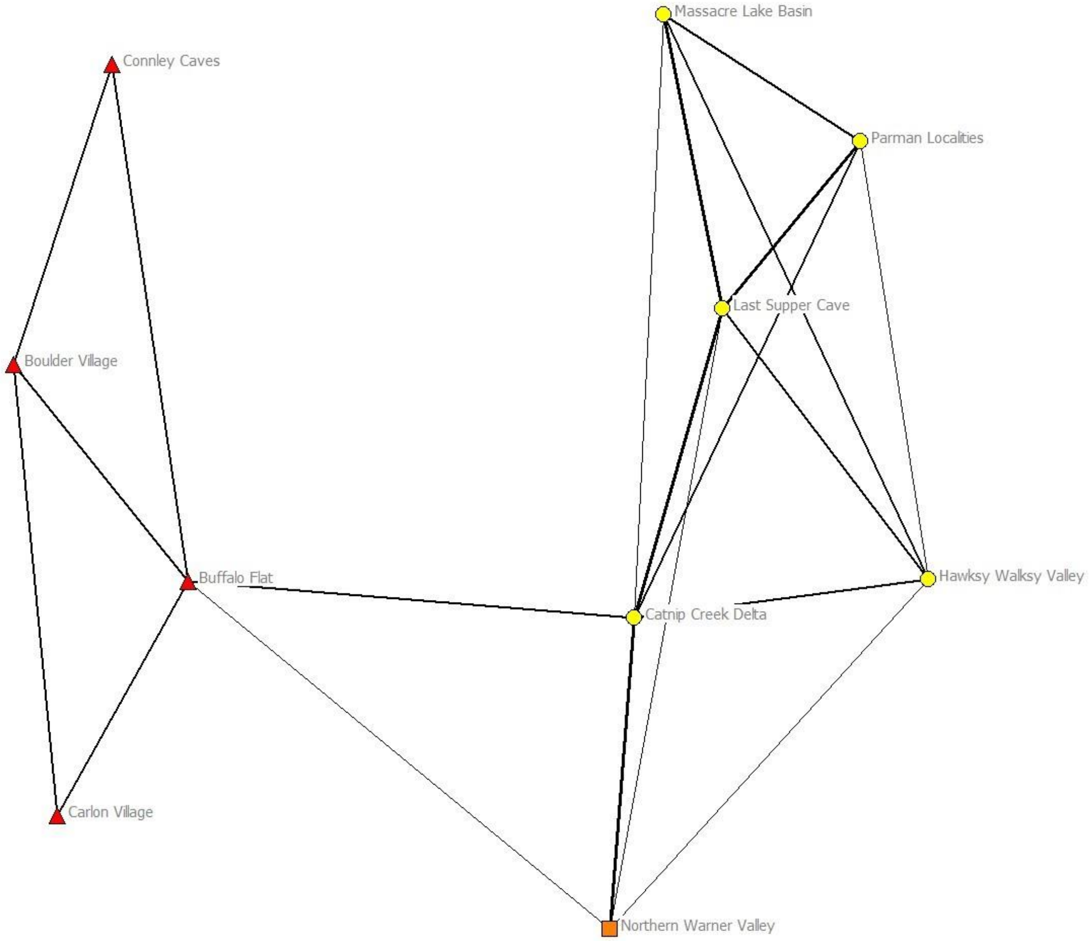

Figure 4.4. The Early Archaic Lithic Network. Circles represent High Rock Country sites and Triangles are central Oregon Sites. Node color is based on the results of the K-Core analysis (Warner Valley is an isolate). Edge thickness is based on the strength of ties between nodes (thicker edge=stronger connection). Buffalo Flat represents the cutpoint assemblage in this network. Note: The Parman Localities were combined in this analysis due to sample size issues.

# Chapter 5:

# CONCLUSIONS

The paucity of well-preserved Terminal Pleistocene/Early Holocene (TP/EH) sites, especially in open-air settings, has long been an issue for Western Stemmed Tradition (WST) researchers in the Great Basin (Smith et al. 2020). Fortunately, the region boasts an abundance of Paleoindian surface sites and toolstone sources amenable to provenance analysis. These surface assemblages and toolstone studies are central to our understanding of WST mobility, territoriality, exchange, and technological organization (e.g., Jones et al. 2003; Madsen 2007; Newlander 2012; Smith 2010). However, the interpretive challenges of surface assemblages (e.g., limited chronological control, few subsistence residues) have left a number of questions unanswered including how WST groups used wetlands, conveyed and procured toolstone, and navigated their social and physical landscapes. The goals of this dissertation have been to: (1) further our understanding of WST settlement-subsistence, territoriality, and lithic technological organization in the northwestern Great Basin through detailed analyses of new and existing lithic assemblages; and (2) explore novel methodologies for analyzing lithic and source provenance data to expand and strengthen our interpretations of Great Basin surface assemblages. In this chapter, I discuss how my research addressed these goals and present avenues for future research.

In Chapter 2, I presented a lithic, source provenance, and spatial analysis of the Catnip Creek Delta (CCD) Locality in Guano Valley, Oregon. The CCD Locality is one of the densest concentrations of WST material in the Great Basin (Reaux et al. 2018). The objectives of this research were to reveal how WST groups used the CCD Locality and relate those findings to existing settlement-subsistence models (e.g., Elston et al. 2014; Jones et al. 2003; Madsen 2007). The results revealed that the CCD Locality contained numerous artifact clusters that primarily consisted of: (1) unhafted bifaces and Early Holocene WST projectile point types; (2) small and homogenous flake tool assemblages; (3) low to moderate tool diversity; (4) high unhafted biface to core and formal to informal tool ratios; and (5) low local to non-local toolstone ratios. These findings supported the Wetland Transient Model and suggest that the CCD Locality record is the product of frequent short-term WST occupations within a larger residentially mobile settlement system. I concluded that the CCD Locality likely represented a reliable retooling and hunting location for WST groups moving between the region's productive wetlands.

In Chapter 3, I further explored WST settlement-subsistence and toolstone procurement strategies by testing a lithic gravity model with the CCD Locality assemblage. Archaeologists have commonly used source provenance research as a basis for understanding WST mobility, exchange, and technological organization (e.g., Jones et al. 2003; Madsen 2007; Newlander 2012; Smith 2010). However, these studies are dominated by problematic methods (Smith and Harvey 2018) and rarely consider the role of source quality in their analyses. My goal in this chapter was to explore a new method of analyzing source provenance data that might alleviate some of the shortcoming of previous studies. To do this, I developed and tested a lithic gravity model. Despite the fact that the model predicted the frequencies of the highest and lowest ranked obsidian sources, most toolstone source frequencies did not correspond with the model's predictions. In many cases, the lowest ranked sources were the most frequently used. These sources were located near wetlands or along likely travel corridors, suggesting that WST groups favored accessibility over quality in procurement decisions. This strategy, bolstered by the region's rich lithic landscape, likely allowed groups to minimize the energetic cost of acquiring toolstone while maximizing overall foraging efficiency as they moved between wetlands.

In Chapter 4, I explored WST and Early Archaic territoriality, exchange, and site connectivity through a social network analysis (SNA) of WST and Early Archaic sites across the northwestern Great Basin. An SNA explores the structure of relationships between actors (e.g., archaeological sites) within a network using mathematical and graphical analysis methods. Elsewhere (Reaux et al. 2018), I proposed that differences in source profile patterning between neighboring Warner Valley and Guano Valley may represent the presence of multiple regional WST populations operating in separate foraging territories. For this study, I used SNA to determine: (1) if multiple WST networks existed in the northwestern Great Basin; (2) how interconnected WST sites were in the region; and (3) how lithic networks changed following the Early-Middle Holocene transition (EMHT). The SNA revealed that the northwestern Great Basin was represented by a single, highly connected lithic network during the TP/EH. This finding is contrary to Jones et al. (2003) and Smith's (2010) views that the region contained two separate lithic conveyance zones. The overall connectivity and size of the lithic network was likely a product of unrestricted socio-political boundaries, low population densities, limited resource competition, and a mobile settlement-subsistence strategy. The Early

Archaic SNA demonstrated that the region became less connected during the EMHT. The change in regional connectivity was likely caused by the desiccation of the region's wetlands and a shift to a less mobile lifestyle.

## Summary of Research

The results of these three studies indicate that: (1) WST groups in the northwestern Great Basin were residentially mobile, focused on wetlands, and likely moved camps regularly; (2) toolstone procurement strategies were based on maximizing efficiency within a wetland centric lifestyle; and (3) the northwestern Great Basin likely contained a single connected Paleoindian network that was probably a product of unrestricted socio-political boundaries, low population densities, limited resource competition, and a mobile settlement-subsistence strategy. Beyond its contributions to WST settlement subsistence, territoriality, exchange, and lithic technological organization, this dissertation highlights some new methods of analyzing lithic and source provenance data that researchers can use to move Great Basin studies forward. In Chapter 2, I used the spatial analysis DBSCAN tool within ArcGIS to identify artifact clusters within the larger CCD Locality that might represent temporally discrete occupations or contemporary activity areas. This method provides a means to tackle palimpsest issues of surface sites if coupled with obsidian hydration or other relative dating methods. In Chapter 3, I presented the first application of a lithic gravity model in the region. This method offers a way to move past the problematic lithic conveyance zone concept (Smith and Harvey 2018). In Chapter 4, I demonstrated how SNA offers an objective way for Great Basin archaeologists to investigate territoriality, the connectivity of sites, and how those connections changed across time and space. Moving forward, researchers may choose to apply some or all these methods to better understand WST lifeways.

## Future Research

Like many research projects, my work has raised new questions and opportunities. First, the CCD Locality remains undated. Placing additional backhoe trenches closer to the artifact concentrations and/or the central channel may be fruitful and help to provide a better understanding of the delta’s history. Additionally, obsidian hydration dating may help to determine if the clusters represent different occupations or contemporary activity areas. Lastly, my work with the CCD Locality has provided a large dataset and testable hypotheses that researchers may use to compare and apply to other assemblages. The gravity model that I presented can be improved upon by incorporating new measures into the equation (e.g., distance to potential wetlands) and strengthening the objectivity of the scoring system. Furthermore, we should collectively continue to map and characterize toolstone sources and make this information publicly available in a centralized location. Doing so will greatly improve both the application of gravity models and our ability to interpret source profiles. Developing and applying gravity models to other WST assemblages in the region may also uncover broader patterns of toolstone procurement decision-making and reveal new insights into Paleoindian settlement-subsistence, territoriality, exchange, and lithic technological organization. Finally, while the SNA I presented provides insight into WST and Early Archaic territoriality and site connectivity, additional research is needed to better understand the full extent of lithic networks in the northwestern Great Basin. Researchers should consider incorporating different datasets into network analyses (e.g., tool metrics, textile styles, rock art motifs) to further explore prehistoric social networks in the region.

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# APPENDIX — SOURCE PROFILES FOR WESTERN STEMMED TRADITION AND EARLY ARCHAIC SITES INCLUDED IN CHAPTER 4

Source Profile for Western Stemmed Tradition Artifacts from Warner Valley and the Central Oregon Sites.

| **Geochemical Type** | **Sites** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Buffalo Flat | Paisley TP | Fort Rock Cave | Connley Caves EH | Connley Caves TP | Cougar Mtn. Cave | North Warner Valley | Paulina Lake Site | **Total** |
| Badger Creek | | | | | | | 1 | | **1** |
| Bald Butte | | | 3 | | 2 | 3 | 1 | | **9** |
| Beatys Butte + B Variety | 1 | | | 1 | 1 | 2 | 9 | | **14** |
| Big Stick | 1 | | | 2 | 3 | | 3 | | **9** |
| Big Obsidian Flow | | | 3 | | | | | 2 | **5** |
| Blue Spring | | | | | | | 1 | | **1** |
| Brooks Canyon | | | | | | 2 | | | **2** |
| Buck Mountain | | | 1 | 2 | 3 | 1 | | 1 | **8** |
| Buck Spring | | | | | | | 1 | | **1** |
| Coglan Buttes | 1 | | | 1 | 6 | | | | **8** |
| Cougar Mountain | | | 27 | 5 | 15 | 32 | | | **79** |
| Connley Hills FGV | | | | 2 | 13 | | | | **15** |
| Cowhead Lake | | | 4 | | 3 | | | 1 | **8** |
| Double O | 2 | | 1 | | | 2 | 1 | | **6** |
| Drews Creek/Butcher Flat | 1 | | | | | | | | **1** |
| Glass Buttes (All Var.) | 3 | | 12 | 2 | 15 | 8 | 3 | | **43** |
| Gregory Creek | | | | | | | 2 | | **2** |
| Hager Mountain | | | 5 | 2 | 1 | 5 | | | **13** |
| Hawks Valley | | | 1 | | 1 | | | | **2** |
| Horse Mountain | 2 | 1 | | 1 | 6 | 7 | 12 | 1 | **30** |
| Indian Creek Buttes | | | | | | | 1 | | **1** |
| Inman Creek A | | | | | | | | 1 | **1** |
| Long Valley | | | | | | | 1 | | **1** |

| **Geochemical Type** | **Sites** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Buffalo Flat | Paisley TP | Fort Rock Cave | Connley Caves EH | Connley Caves TP | Cougar Mtn. Cave | North Warner Valley | Paulina Lake Site | **Total** |
| Massacre Lake/Guano Valley | | 1 | 1 | | | | 5 | | **7** |
| McComb Butte | 1 | | | | | | | | **1** |
| McKay Butte | | | 8 | 1 | | 7 | | 8 | **24** |
| Mosquito Lake | | | | | | | 1 | | **1** |
| Mud Ridge | | | | | | | 1 | | **1** |
| Obsidian Cliffs | | | 1 | | | | | 1 | **2** |
| Quartz Mountain | 1 | 1 | 17 | 5 | 7 | 9 | | | **40** |
| Riley | 1 | | | | | | | | **1** |
| Round Top Butte | 1 | | 1 | | | 2 | | | **4** |
| Silver Lake/Sycan Marsh | 4 | | 23 | 3 | 10 | 9 | 1 | 6 | **56** |
| Spodue Mountain | 2 | | 9 | 2 | 8 | 7 | | 8 | **36** |
| Sugar Hill | | | | | 7 | | 1 | | **8** |
| Tank Creek | | | | | | 1 | 2 | | **3** |
| Tucker Hill | | 4 | 1 | 3 | 3 | 3 | 2 | | **16** |
| Tule Spring | | | | | | | | 2 | **2** |
| Variety 5 | | | | 2 | 1 | 2 | | | **5** |
| Venator | | | | | 2 | | | | **2** |
| Wagontire | | | | | 1 | 1 | 2 | | **4** |
| West Mckay Butte | | | | | | | | 1 | **1** |
| Whitewater Ridge | | | 1 | | | | | | **1** |
| Wildhorse Canyon | | | | | | | 1 | | **1** |
| Yreka Butte | | | 4 | 1 | 3 | 10 | 2 | | **20** |
| **Total** | **21** | **7** | **123** | **35** | **111** | **113** | **54** | **32** | **496** |

Note: EH=Early Holocene; TP=Terminal Pleistocene.

Source Profile for Western Stemmed Tradition Artifacts from High Rock Country Sites.

| **Geochemical Type** | **Sites** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CCD | Hawksy Walksy | LSC | Hanging Rock Shelter | Parman Loc. 1 | Parman Loc. 2 | Parman Loc. 3 | Parman Loc. 4 | BRD WA | BRD EA | Rock Creek | **Total** |
| Alturas FGV | 6 | | | | | | | | | | | **6** |
| Badger Creek | 35 | 7 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | | 2 | **53** |
| Beatys Butte + B Variety | 88 | 27 | 4 | | 4 | | 1 | | 1 | 2 | | **127** |
| Big Stick | | | | | | | | 1 | | | | **1** |
| Blue Spring | 4 | | | | | | | | | | 2 | **6** |
| BS/PP/FM | 7 | 4 | 2 | 7 | 2 | 2 | 4 | | 16 | 3 | 1 | **48** |
| Buck Mountain | 29 | 6 | 1 | 2 | 1 | | 1 | | 2 | 1 | 3 | **46** |
| Buffalo Hills | | | | 1 | | 1 | | | 2 | 1 | | **5** |
| Cowhead Lake | 44 | 6 | | 2 | 1 | 1 | 2 | | | | 12 | **68** |
| Coyote Springs FGV | 14 | 7 | 1 | 2 | 1 | 2 | 2 | 4 | 5 | | | **38** |
| Coyote Wells | 1 | 1 | | | | | | | | | | **2** |
| Craine Creek | | 2 | 1 | | 2 | 2 | 3 | 1 | | | | **11** |
| DH/W | 9 | 9 | 1 | | 1 | 1 | 8 | 3 | 1 | 9 | | **42** |
| Double O | 2 | 3 | | | | | | | | | | **5** |
| DC/BF | 1 | | | | | | | | | | | **1** |
| Glass Buttes (All Var.) | 5 | | | | | | | | | | | **5** |
| GF/LIW/RS | 2 | | | | | | | | | | | **2** |
| Hawks Valley | 18 | 52 | 2 | 1 | | 2 | 6 | 2 | | 4 | | **87** |
| Horse Mountain | 7 | | | | | | | | | | | **7** |
| Indian Creek Buttes | 1 | 2 | | | 1 | | | | | | | **4** |
| Long Valley | 13 | 1 | | | 2 | | 1 | | | | 1 | **18** |
| ML/GV | 206 | 50 | 22 | 11 | 11 | 13 | 24 | 14 | 12 | 11 | 2 | **376** |
| Mosquito Lake | 29 | 5 | | | | | | | | | 2 | **36** |
| Mount Majuba | | 1 | | | | | | | 1 | | | **2** |
| Paradise Valley | | | | | | | | | | 4 | | **4** |
| Quartz Mountain | 1 | | | | | | | | | | | **1** |
| Rainbow Mines | 5 | | | | | | | | | 6 | | **11** |

| **Geochemical Type** | **Sites** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CCD | Hawksy Walksy | LSC | Hanging Rock Shelter | Parman Loc. 1 | Parman Loc. 2 | Parman Loc. 3 | Parman Loc. 4 | BRD WA | BRD EA | Rock Creek | **Total** |
| Riley | 1 | | | | | | | | | 1 | | **2** |
| Spodue Mountain | 1 | | | | | | | | | | | **1** |
| Sugar Hill | 4 | 1 | | | | | | | | | 1 | **6** |
| Surveyor Spring | 6 | | | 1 | 1 | | | | | | 5 | **13** |
| Tank Creek | 1 | | | | | | | | | | | **1** |
| Tucker Hill | | 1 | | | | | | | | | | **1** |
| Venator | 1 | 4 | | 1 | | | 1 | 1 | | | | **8** |
| Wagontire | 2 | | | | | | | | | | | **2** |
| Warner Valley FGV | 1 | | | | | | | | | | | **1** |
| Whitewater Ridge | 1 | | | 1 | | | | | | | | **2** |
| **Total** | **545** | **189** | **35** | **30** | **29** | **25** | **55** | **27** | **41** | **42** | **31** | **1049** |

Note: BS/PP/FM=Bordwell Springs/Pinto Peak/Fox Mountain; DH/W=Double H/Whitehorse; DC/BF=Drews Creek/Butcher Flat; GF/LIW/RS=Grasshopper Flats/Lost Iron Well/Red Switchback; ML/GV=Massacre Lake/Guano Valley, FGV=Fine Grained Volcanic; CCD=Catnip Creek Delta; LSC=Last Supper Cave.

Source Profile for Northern Side Notched Points.

| **Geochemical Type** | **Sites** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Carlon Village | Boulder Village | Connolly Caves | Buffalo Flat | N Warner Valley | Massacre Lake Basin | CCD | Hawksy Walksy | Parman Localities | LSC | Total |
| Badger Creek | | | | | | 1 | | | 1 | 5 | **7** |
| Bald Butte | 1 | | | | | | | | | | **1** |
| Beatys Butte + B Variety | | | | | 1 | | 3 | 1 | | | **5** |
| BS/PP/FM | | | | | | 1 | | | | 4 | **5** |
| Buck Mountain | | | | | | 2 | | 1 | | | **3** |
| Buck Spring | | | | | 1 | | | | | | **1** |
| Coglan Buttes | | | 1 | | | | | | | | **1** |
| Cougar Mountain | 1 | 2 | | 4 | | | | | | | **7** |
| Cowhead Lake | | | | | 2 | | 2 | | | 1 | **5** |
| Coyote Springs FGV | | | | | | | | | | 1 | **1** |
| Craine Creek | | | | | | | 1 | | 1 | 2 | **4** |
| Double H/Whitehorse | | | | | | | | 1 | | 2 | **3** |
| Double O | | | | 1 | 1 | | 1 | | | | **3** |
| DC/BF | | | 1 | | | | | | | | **1** |
| East Medicine Lake | | 1 | | | | | | | | | **1** |
| Glass Buttes (All Var.) | 1 | 1 | | 1 | | | | | | | **3** |
| Hawks Valley | | | | | | | | | | 2 | **2** |
| Long Valley | | | | | | | | | | 4 | **4** |
| ML/GV | | | | | | 6 | 21 | 7 | 1 | 29 | **64** |
| McComb Butte | | | | 1 | | | 1 | | | | **2** |
| Mosquito Lake | | | | | | | 2 | | | | **2** |
| Mount Majuba | | | | | | | | | 1 | | **1** |
| SL/SM | | | 3 | 3 | | | | | | | **6** |

| Geochemical Type | Sites | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Carlon Village | Boulder Village | Connolly Caves | Buffalo Flat | N Warner Valley | Massacre Lake Basin | CCD | Hawksy Walksy | Parman Localities | LSC | Total |
| Spodue Mountain | | | 1 | 3 | | | | | | | **4** |
| Sugar Hill | | | | | | | 1 | | | | **1** |
| Squaw Ridge | | | | 1 | | | | | | | **1** |
| Tank Creek | | | | | 1 | | | | | | **1** |
| Tucker Hill | | | | | 1 | | | | | | **1** |
| Variety 5 | 1 | | | | | | | | | | **1** |
| **Total** | **4** | **4** | **6** | **14** | **7** | **10** | **32** | **10** | **4** | **50** | **141** |

Note. BS/PP/FM=Bordwell Springs/Pinto Peak/Fox Mountain; LSC=Last Supper Cave; CCD=Catnip Creek Delta; ML/GV=Massacre Lake/Guano Valley; DC/BF=Drews Creek/Butcher Flat; SL/SM=Silver Lake/Sycan Marsh.